User Manual

Giganetix Camera Family

SMARTEK Vision
Business Class Products at Economy Prices

For customers in the U.S.A.

The equipment provided in an enclosure / housing has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Modifications not expressly approved in this manual could void the user's authority to operate the equipment under FCC rules.

For customers in Canada

This apparatus complies with the Class A limits for radio noise emissions set out in the Radio Interference Regulations.

Pour utilisateurs au Canada

Cet appareil est conforme aux normes classe A pour bruits radioélectriques, spécifiées dans le Règlement sur le brouillage radioélectrique.

Life support applications

These products are not designed for use in life support systems, appliances or devices where mal- function of the products can reasonably be expected to result in personal injury. Customers, Integrators and End Users using or selling these products for use in such applications do so at their own risk and agree to fully indemnify SMARTEK d.o.o. for any damages resulting from any improper use or sale.

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Warranty

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1 Description of Product Family

The SMARTEK Vision Giganetix camera family offers an affordable, easy to use set of digital cameras designed to meet demanding high quality image machine vision applications conforming to the industrial GigE Vision standard. The compact housings fit almost every space critical application. A wide selection of Sony, Aptina and Truesense Imaging CCD and CMOS sensors delivers images with high sensitivity and low noise. Excellent price to performance ratio makes this portfolio the perfect choice for every demanding user.

SMARTEK Vision Giganetix cameras combine standard Gigabit Ethernet technology with the GigEVisionSDK image acquisition software to reliably capture and transfer images from the camera to the PC. All Giganetix cameras are supported by one Software Development Kit as well as a large number of 3rd-party libraries compliant to the GigE Vision Standard. To use these devices with other software than provided by SMARTEK Vision, please check their user guides.

Ultra small compact form	Precise image sensor alignment
Sony, Aptina and Truesense Imaging CCD and CMOS sensors	Built-in IR cut-off filter in color models (optional for monochrome models)
Long cable length up to 100m	Standard C-Mount lens adapter
Use of low cost Cat5e or Cat6 Ethernet cables	90° angled and board level versions
Low power consumption, low thermal dissipation	Excellent thermal linkage between sensor and housing
Pixel depth of up to 14bit	Horizontal and vertical binning*
Very small trigger latency 2µs, jitter < 0.5µs	Opto-isolated inputs and outputs
Partial scan and region of interest functions*	Very competitive price to performance ratio
High frame rates or high sensitivity option*	Firmware update via SDK over Ethernet
Black anodized aluminum housing	Rubber sealed image sensor space
Internal image buffer for retransmission and reliability (packet resend mechanism)	Industrial connectors: EIAJ (Hirose)-12 pin and screw mount RJ45

* model specific feature

Table 1: Key Benefits and Features

1.1 Precautions

Due to the ultra-small compact housing of the camera, it has a tendency to develop a high temperature. To maintain an optimal working temperature, mount the camera on a metal surface.

Do not attempt to disassemble this camera; there are sensitive optical parts inside. Tampering with it could lead to permanent damage.

Do not expose this camera to rain or moisture. This device is not intended to work under wet conditions.

Do not face this camera towards the sun, extremely bright light or light reflecting objects. Even when the camera is not in use, put the supplied lens cap on the lens mount, to prevent damage to the sensor

Handle this camera with the maximum care. Do not throw the device; there are fragile glass parts inside.

Operate this cameras only with the type of power source that meets the specifications indicated on the camera and within the documentation. Operating the camera outside of the specifications can cause to permanent damage. Further electrical specifications can be found in chapter 2.1 - Mechanical and Electrical specifications.

1.2 Supported Industry Standards

1.2.1 GigE Vision

GigE Vision is a communication interface standard for high-performance industrial cameras based on the Gigabit Ethernet technology. The main idea driving the development of the standard is to unify different protocols used in machine vision industrial applications and make hardware and software from various vendors interoperate seamlessly over GigE connections. GigE Vision is administered by the *Automated Imaging Association* (AIA).

Features of the GigE Vision standard:

- Fast data transfer rates - up to 1 Gbit/s (based on 1000BASE-T)
- Data transfer length up to 100m exceeding maximum length of FireWire, USB and Camera Link interfaces.
- Based on established standard allowing communication with other Ethernet devices and computers.

GigE Vision has four main elements:

- *GigE Vision Control Protocol* (GVCP) - runs on the UDP protocol. The standard defines how an application controls and configures devices, and instantiates stream channels on the device. It also defines the way for the device to notify an application about specific events.
- *GigE Vision Stream Protocol* (GVSP) - covers the definition of data types and the ways images and other data are transferred from device to application.
- *GigE Device Discovery Mechanism* - provides mechanisms for a device to obtain valid IP address and for an application to enumerate devices on the network.
- *XML description* - file based on the GenICam standard which provides the mapping between a device feature and the device register implementing the feature.

1.2.2 GenICam

GenICam (Generic Interface for Cameras) is a generic programming interface for machine vision cameras. The goal of the standard is to decouple industrial camera interface technology (such as GigE Vision, Camera Link, USB or FireWire) from the user application programming interface (API). GenICam is administered by the *European Machine Vision Association* (EMVA).

GenICam consists of three modules to help solve the main tasks in machine vision field in a generic way. These modules are:

- *GenApi* - configures the camera and details how to access and control cameras by using an XML description file.
- *Standard Feature Naming Convention* (SFNC) - are the recommended names and types for common features in cameras to promote interoperability
- *GenTL* - is the transport layer interface for enumerating cameras, grabbing images from the camera, and moving them to the user application.

GenICam provides supports for five basic functions:

- Configuring the camera - supports a range of camera features such as frame size, acquisition speed, pixel format, gain, image offset, etc.
- Grabbing images - creates access channels between the camera and the user interface and initiates receiving images.
- Graphical user interface - enables user GUI interface to seamlessly talk to the camera(s).
- Transmitting extra data - enables cameras to send extra data on top of the image data. Typical examples could be histogram information, time stamp, area of interest in the frame, etc.
- Delivering events - enables cameras to talk to the application through an event channel

Standard Features Naming Convention (SFNC)

SFNC provides the definitions of standard use cases and standard features. The goal is to cover and to standardize the naming convention used in all those basic use cases where the implementation by different vendors would be very similar anyway. The GenICam technology allows exposing arbitrary features of a camera through a unified API and GUI. Each feature can be defined in an abstract manner by its name, interface type, unit of measurement and behavior. The GenApi module of the GenICam standard defines how to write a camera description file that describes a specific camera's mapping.

For detailed information about this convention visit www.emva.org.

1.2.3 C-Mount

A *C-Mount* is a type of lens mount commonly found on 16mm movie cameras, closed-circuit television cameras (CCTV), trinocular microscope photo tubes and CCD/CMOS digital cameras. C-Mount lenses provide a male thread which mates with a female thread on the camera. The thread is nominally 25.4mm [1"] in diameter, with 32 threads per inch, designated as ”1-32 UN 2A” in the ANSI B1.1 standard for unified screw threads. The flange focal distance is 17.526mm [0.69"] and thread length 3.8mm [0.15"].

1.3 EMI and ESD Consideration

Excessive EMI and ESD can cause problems with your camera such as false triggering or can cause the camera to suddenly stop capturing images. EMI and ESD can also have a negative impact on the quality of the image data transmitted by the camera.

To avoid problems with EMI and ESD, you should follow these general guidelines:

- Use high quality shielded cables. The use of high quality cables is one of the best defenses against EMI and ESD.
- Try to use camera cables with correct length and try to run the camera cables and power cables parallel to each other. Avoid coiling camera cables.
- Avoid placing camera cables parallel to wires carrying high-current, switching voltages such as wires supplying stepper motors or electrical devices that employ switching technology.
- Attempt to connect all grounds to a single point, e.g. use a single power outlet for the entire system and connect all grounds to the single outlet.
- Use a line filter on the main power supply.
- Install the camera and camera cables as far as possible from devices generating sparks.
- Decrease the risk of electrostatic discharge by taking the following measures:
- Use conductive materials at the point of installation.
- Use suitable clothing (cotton) and shoes.
- Control the humidity in your environment. Low humidity can cause ESD problems.

1.4 Supported Third-Party Software

The Giganetix cameras have been verified to be applicable with the third-party software shown below in Table 2.

Software	Requirements
Cognex Vision Pro	Native (GigEVision interface)
Matrox Imaging Library	Native (GigEVision interface)
MVTec Halcon	Native (GigEVision interface)
National Instruments LabView	National Instruments IMAQdx (Plugin)
Scorpion Vision	Plugin provided by SMARTEK Vision

Table 2: Third-Party Software

2 SMARTEK Vision Giganetix Camera Models

The Giganetix camera family consists of a line-up of GigE Vision compliant cameras equipped with a selection of CCD and CMOS sensors, fitted into several different camera designs. The following chapter contains the hardware specification of the single camera series and their different models, including technical drawings. Table 3 gives a brief overview about the unique characteristics of each series.

Type	Short Description
GC (standard housing)	Standard Giganetix Camera
GC-S90 (angled 90° housing)	Standard Giganetix Camera with 90° angled housing. For applications with very limited space in optical axis and other mechanical restrictions, making the standard housing unsuitable.
GC-BL (board level)	90° Board level version of the standard Giganetix Camera with a single mainboard and detached sensor head. Suitable for OEM and special solutions where a camera needs to be integrated into a closed device and/or a housed camera does not fit into the design.
GCP (standard housing)	Enhanced version of the Giganetix Camera in an adapted mechanical design providing a set of high-end sensors and increased hardware capabilities, as well as Power over Ethernet by default.

Table 3: Giganetix Family Camera Lines

2.1 Mechanical and Electrical Specifications

2.1.1 Giganetix with Standard Housing (GC Series)

The Giganetix camera series with standard housing represents the regular camera design for the GC series with the main focus on a small form factor, offering the comprehensive camera electronics in a small 35x35x48 mm footprint. Figure 1 shows an image of the housing. Table 4 contains an overview about the model specific specifications.

Figure 1: Giganetix Camera with Standard Housing

External dimensions (H x W x L)	35 x 35 x 48 [mm]	1.38 x 1.38 x 1.89 [in]
Housing	Black anodized aluminum case	
Weight	Approx. 90g	3.2oz
Storage temperature[1]	-30°C to +60°C	-22°F to +140°F
Operating temperature[1]	0°C to +50°C	+32°F to +122°F
Operating humidity	20% to 80%, relative, non-condesing	
Storage humidity	20% to 80%, relative, non-condesing	
Power requirement	10V to 24V DC via Power and I/O-interface, Power over Ethernet (PoE)	
Lens mount	C-Mount	
Connectors	Screw mount Ethernet RJ45 (Communication and Data), Circular Hirose 12 pin (Power and I/O-Interface)	
Digital input	2 input channels, opto-isolated	
Digital output	2 output channels, opto-isolated	
Conformity	CE, FCC, RoHS, GigE Vision, GenICam, PoE (IEEE802.3af)	

[1] measured at camera housing

Table 4: Mechanical and electrical specifications

2.1.1.1 Technical Drawings

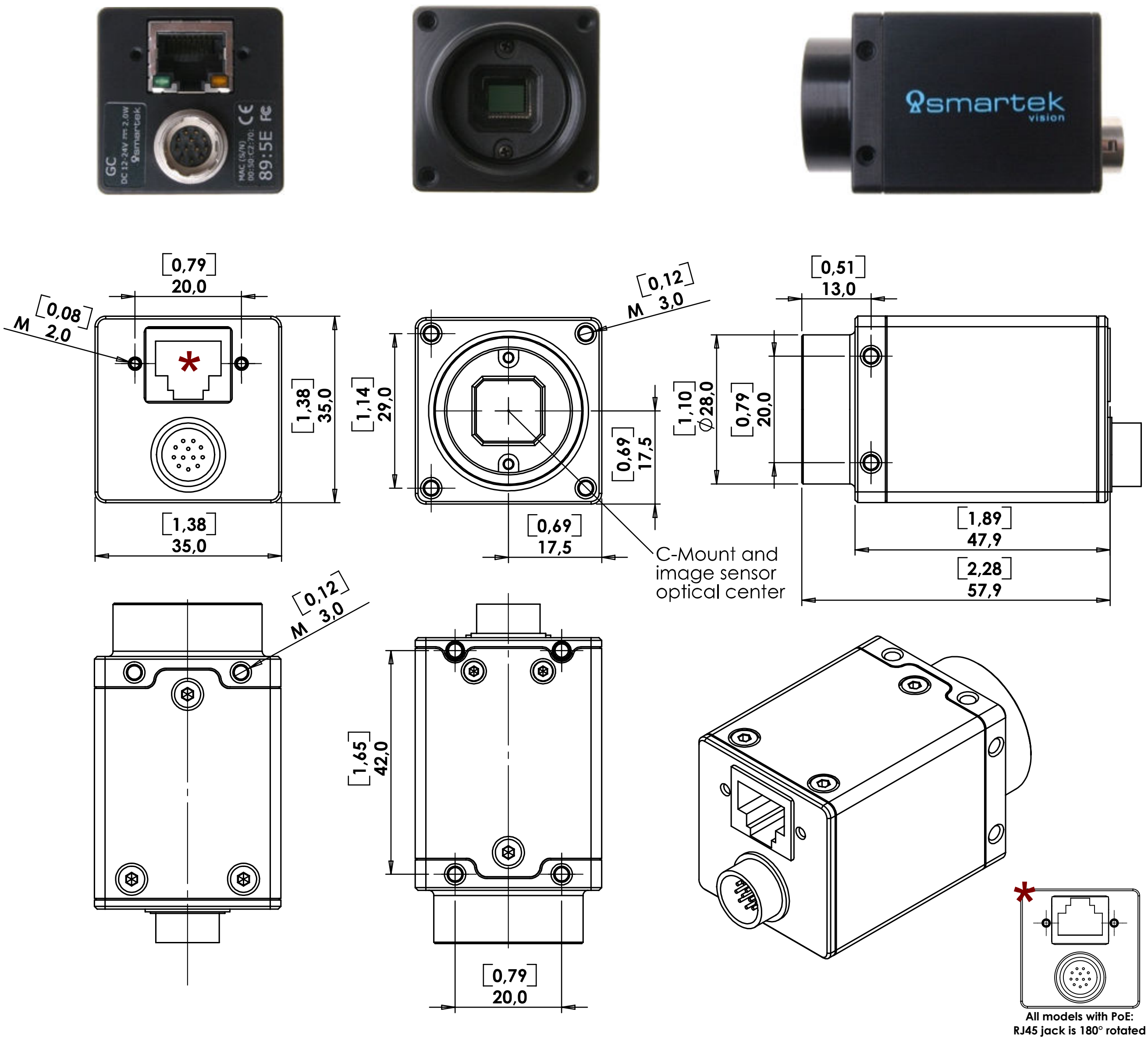


Figure 2: Technical measures of standard camera housing (all dimensions are in mm [inch])

2.1.2 Giganetix with 90° Angled Housing (GC-S90 Series)

The 90° angled version of the Giganetix camera series is identical to the standard GC camera, fitted into a different form factor to enhance its flexibility. It aims on very build-up applications and all such with limited space in sensor axis. Due to its non-symmetrical housing the GC-S90 series supports image mirroring to reverse the image about its X- and Y-Axis to allow a most possible flexibility in positioning.

Figure 3: Giganetix Camera with 90° angled housing

External dimensions (H x W x L)	35 x 35 x 75 [mm]	1.38 x 1.38 x 2.95 [in]
Housing	Black anodized aluminum case with 90° angled sensor and lens mount	
Weight	Approx. 120g	approx. 4.2oz
Storage temperature[1]	-30°C to +60°C	-22°F to +140°F
Operating temperature[1]	0°C to +50°C	+32°F to +122°F
Operating humidity	20% to 80%, relative, non-condesing	
Storage humidity	20% to 80%, relative, non-condesing	
Power requirement	10V to 24V DC via Power and I/O-interface	
Lens mount	C-Mount	
Connectors	Screw mount Ethernet RJ45 (Communication and Data), Circular Hirose 12 pin (Power and I/O-Interface)	
Digital input	2 input channels, opto-isolated	
Digital output	2 output channels, opto-isolated	
Conformity	CE, FCC, RoHS, GigE Vision, GenICam	

[1] measured at camera housing

Table 5: Mechanical and electrical specifications

2.1.2.1 Technical Drawings

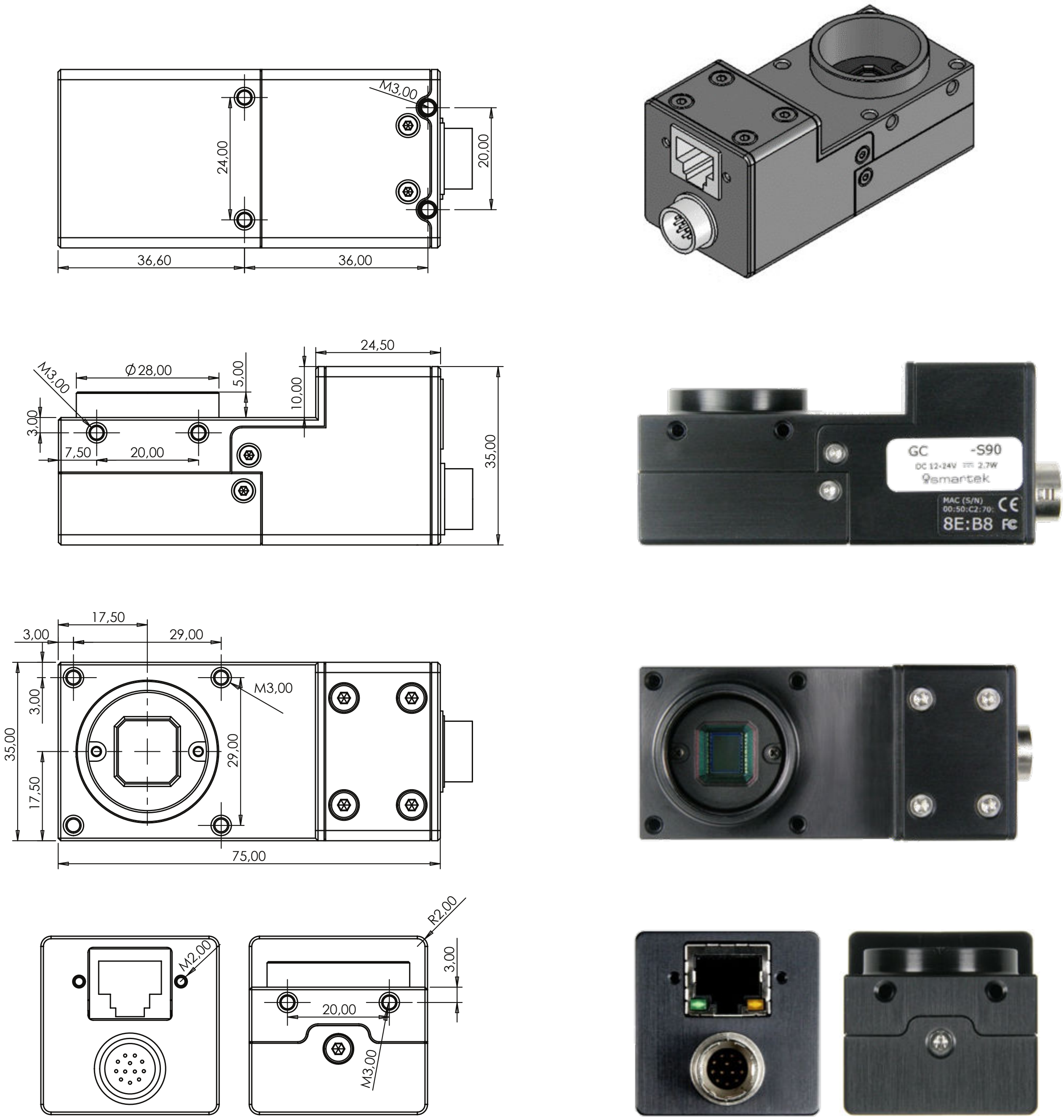


Figure 4: Technical measures of angled 90° camera housing (all dimensions are in mm [inch])

2.1.3 Giganetix Board Level (GC-BL Series)

The board level version of the Giganetix camera series aims on the OEM integration of the camera into closed customer devices. It provides the complete electrical design of the GC mainboard on a single board, having a separated sensor head supporting cable lengths of up to 150 mm.

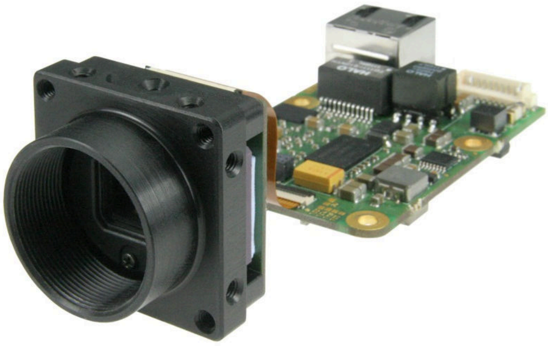


Figure 5: Giganetix Board Level Camera

External dimensions (H x W x L)	35 x 35 x 26.2 [mm]	Sensor board	1.38 x 1.38 x 1.03 [in]
	65 x 43 x 19 [mm]	Head board	2.56 x 1.69 x 0.75 [in]
Housing	No housing sensor head and mainboard only, connected via FPC cable		
Weight	Approx. 60g		approx. 2.1oz
Storage temperature[1]	-30°C to +60°C		-22°F to +140°F
Operating temperature[1]	0°C to +45°C		+32°F to +113°F
Operating humidity	20% to 80%, relative, non-condesing		
Storage humidity	20% to 80%, relative, non-condesing		
Power requirement	10V to 24V DC via Power and I/O-interface, Power over Ethernet (PoE)		
Lens mount	C-Mount		
Connectors	Screw mount Ethernet RJ45 (Communication and Data), Circular Hirose 12 pin (Power and I/O-Interface)		
Digital input	2 input channels, opto-isolated		
Digital output	2 output channels, opto-isolated		
Conformity	RoHS, GigE Vision, GenICam, PoE (IEEE802.3af)		

[1] measured at the direct board environment

Table 6: Mechanical and electrical specifications

Equal to the GCP series, the board level version is equipped with the latest version of the camera's power supply and supports Power over Ethernet. Due to the large dimensioned components also sensors with an increased power consumption, like multi-tap CCDs, are supported.

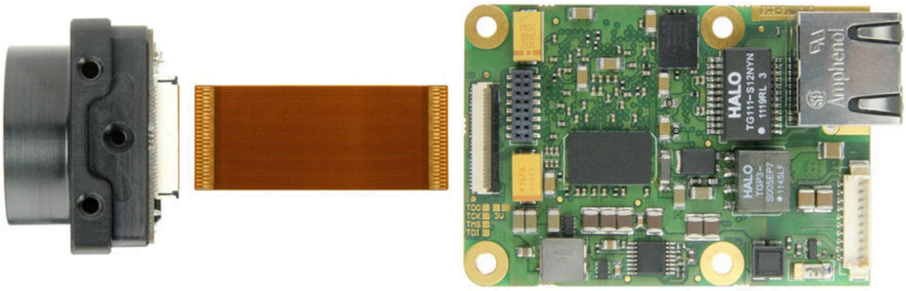


Figure 6: GC-BL - Sensor head, FPC cable and mainboard (from left to right)

Note For assembling instructions please refer to the GC-BL *Assemble Guide* available on www.SMARTEKvision.com/downloads.php after reading the following safety instructions carefully.

2.1.3.1 Further Precautions for Board Level Cameras

Before the first operation of a Giganetix Board Level camera, please read the following safety instructions and cautions carefully. Abuse and misapplication may lead to limited or canceled warranty.

ESD Cautions:

All boards of the camera are sensitive to electrostatic discharge. Handle all components of the camera only in static-save areas and make sure that no electrostatic loads from your body are discharged to any of the boards:

- Discharge yourself on a grounded body before touching
- Work in a static-safe work area on an antistatic mat
- Wear an antistatic-wrist strap the whole time handling the camera boards
- Do not hold any of the camera's components to you clothing

General Cautions:

The board level cameras are delivered without a housing and partly disassembled. Handle all parts with care and do not touch the components or contacts on the boards; hold all boards only by their edges.

The cable used to connect sensor head and mainboard is a Flat Printed Circuit (FPC) cable. Due to the construction of cable and jack it is not build for re-plugging or multiple bending cycles; physical stress to cable or connector can lead to permanent damage.

Do not attempt to disassemble the lens mount or sensor head; there are sensitive optical parts inside, tampering can lead to permanent damage.

Building a case around the camera causes in a heat accumulation of the internal ambient temperature. Make sure that the environmental temperature of the camera electronics does not exceed the specified maximum.

Environmental and Mechanical Cautions:

Due to the missing housing the camera is not certified to any EMC directives. The customer needs to take care of fulfilling EMC regulations for his individual target application and for sufficiently shielding the camera against environmental radiation.

Avoid the contact of the of the camera's boards with any liquid or any impurities; do only operate clean boards and protect them against environmental influences like particles, humidity, liquids and radiation by an appropriate protective housing.

Avoid any mechanical forces like torsion, tension and compression, e.g. by mounting the boards or the cabling. Make sure that no forces are induced to the connectors by using sufficient cable pull reliefs.

2.1.3.2 Technical Drawings

Sensor Head Dimensions (C-Mount):

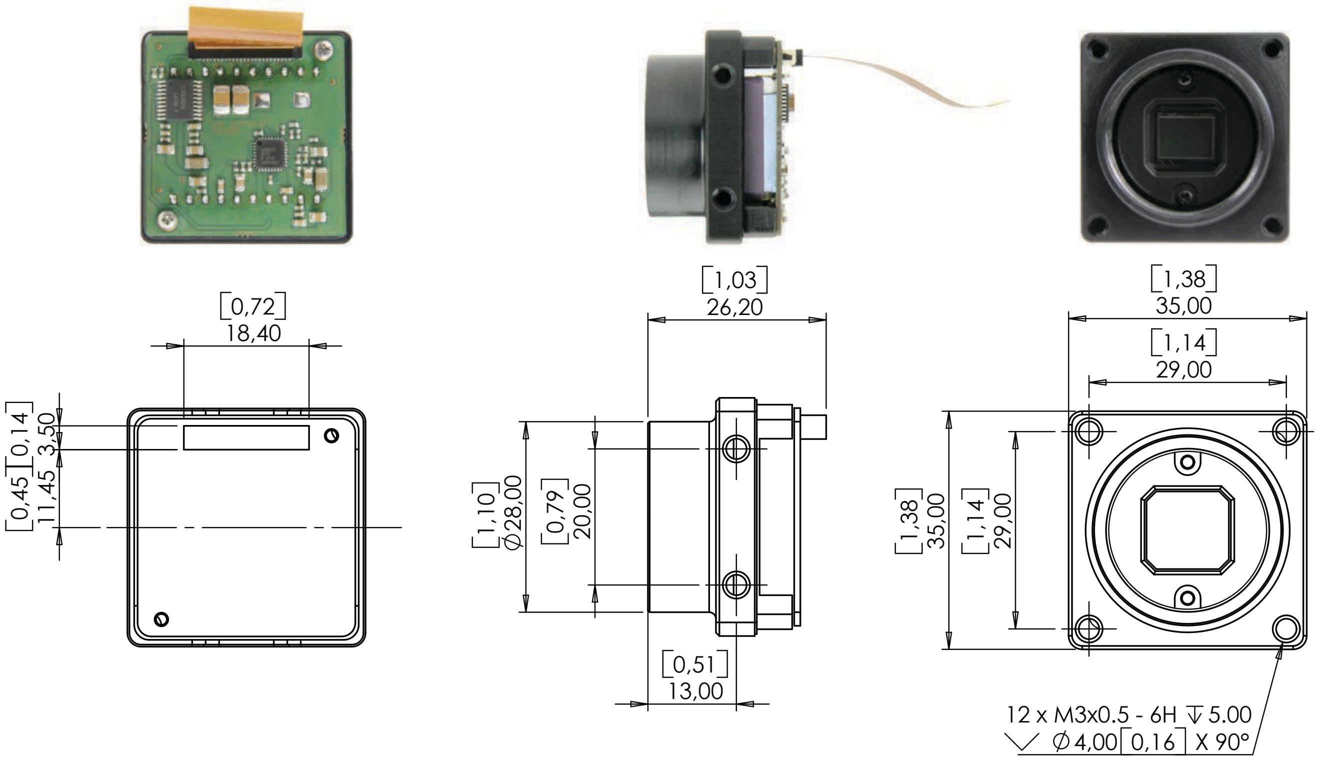


Figure 7: Technical measures of board level sensor head (all dimensions are in mm [inch])

Mainboard Dimensions:

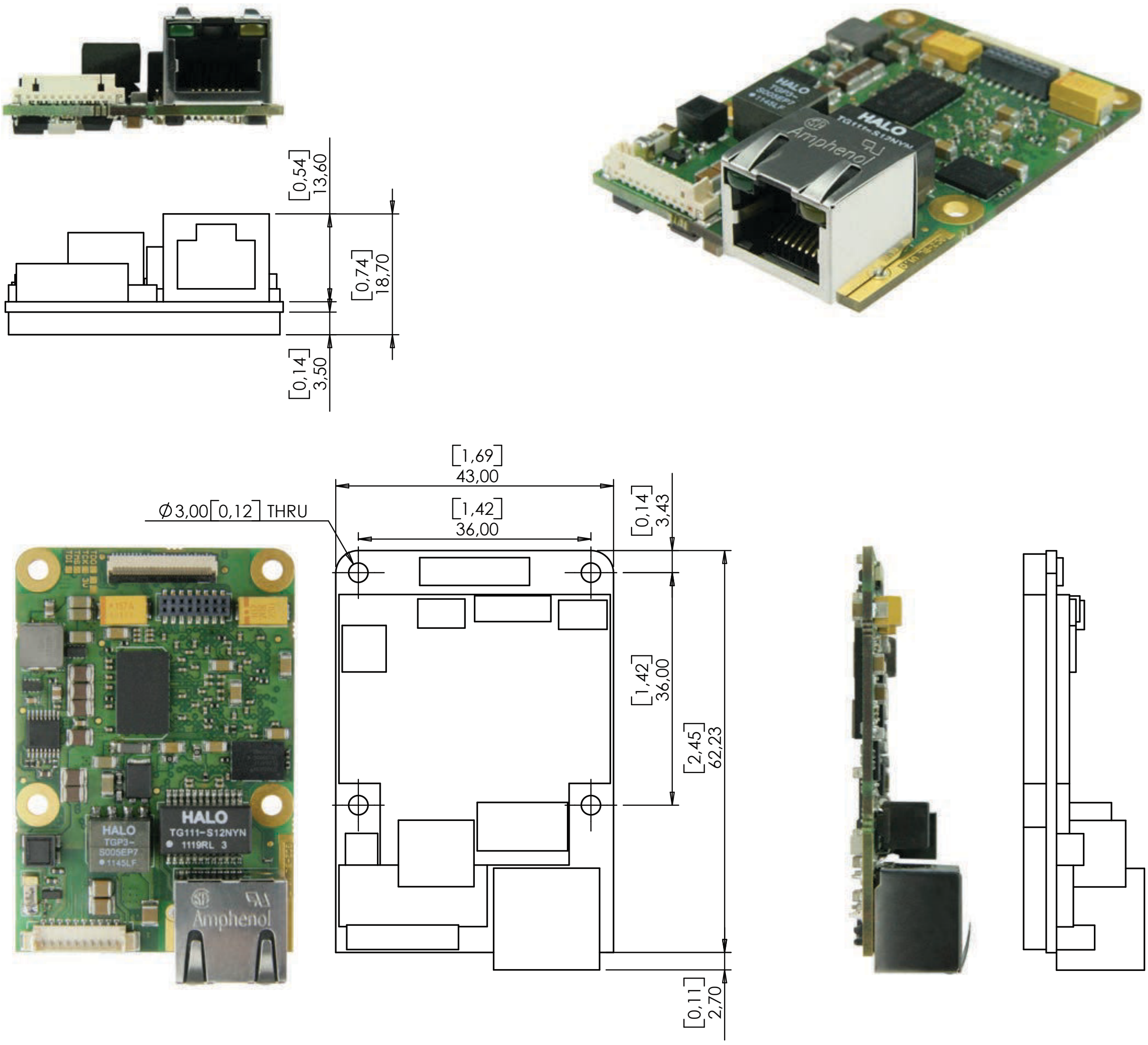


Figure 8: Technical measures of board level mainboard (all dimensions are in mm [inch])

2.1.4 Giganetix Plus Camera with Standard Housing (GCP Series)

The Giganetix Plus camera series is the enhanced version of the GC camera and allows with its extended hardware the integration of larger high-end sensors with higher data rates. Thanks to its well-spaced hardware it supports features like the factory based tab calibration and allows the integration of further image processing features, right up to fully customer specific implementations.

Figure 9: Giganetix Plus Camera with standard housing

External dimensions (H x W x L)	50 x 50 x 48 [mm]	1.97 x 1.97 x 1.89 [in]
Housing	Black anodized aluminum case	
Weight	Approx. 150g	5.3oz
Storage temperature[1]	-30°C to +60°C	-22°F to +140°F
Operating temperature[1]	0°C to +50°C	+32°F to +122°F
Operating humidity	20% to 80%, relative, non-condesing	
Storage humidity	20% to 80%, relative, non-condesing	
Power requirement	10V to 24V DC via Power and I/O-interface, Power over Ethernet (PoE)	
Lens mount	C-Mount	
Connectors	Screw mount Ethernet RJ45 (Communication, Data and Power), Circular Hirose 12 pin (Power and I/O-Interface)	
Digital input	2 input channels, opto-isolated	
Digital output	2 output channels, opto-isolated	
Conformity	CE, FCC, RoHS, GigE Vision, GenICam, PoE (IEEE802.3af)	

[1] measured at camera housing

Table 7: Mechanical and electrical specifications

2.1.4.1 Technical Drawings

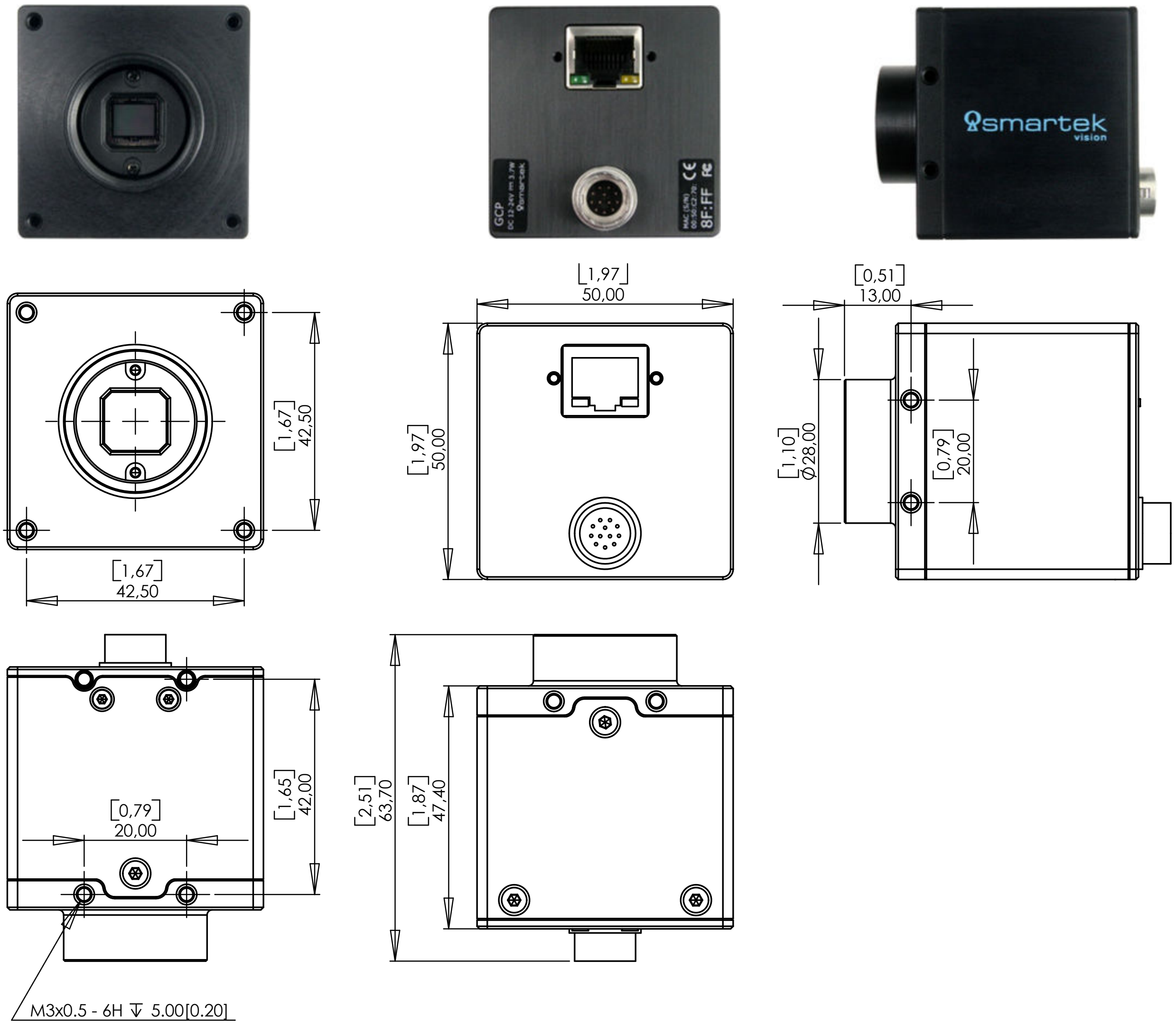


Figure 10: Technical measures of GCP camera with standard housing (all dimensions are in mm [inch])

2.2 Sensor Information and Technical Specification (All Models Separate)

The following chapter contains sensor specific specifications for all existing camera models, including the respective response curves. All respond curves have been extracted from the datasheet of the sensor manufacturer.

2.2.1 GC1281M

	GC	GC-S90	GC-BL
Image Sensor		Aptina MT9M001	
Chromatics		Monochrome	
Sensor type		CMOS	
Sensor resolution (H x W)		1280 x 1024	
Optical size		1/2"	
Pixel size (in µm)		5.2 x 5.2	
Analog gain (in dB)		0 to 23.5	
Shutter		Rolling	
Exposure time		32µs to 0.5s	
Max. frame rate (8Bit; in Hz)		30	
ADC bit depth		8 bit	
Pixel data formats		Mono8	
Synchronization		Free run, external and software trigger (single shot, multi shot)	
Exposure control		Freely programmable via GigE Vision interface	
Power consumption (aux. / 12V)	2.3W	2.3W	2.3W
Power consumption (PoE)	3.0W	Not supported	3.0W

Table 8: Model specific specification of GC1281M

Relative Response

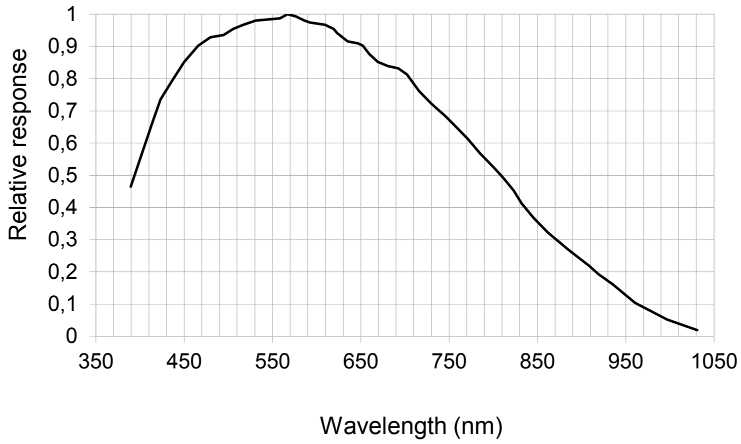


Figure 11: Relative response of GC1281 Monochrome (from sensor datasheet)

2.2.2 GC2041C

	GC	GC-S90	GC-BL
Image Sensor	Aptina MT9T031		
Chromatics	Color		
Sensor type	CMOS		
Sensor resolution (H x W)	2048 x 1536		
Optical size	1/2"		
Pixel size (in µm)	3.2 x 3.2		
Analog gain (in dB)	0 to 23.5		
Shutter	Rolling		
Exposure time	53µs to 10s		
Max. frame rate (8Bit; in Hz)	12		
ADC bit depth	8 bit		
Pixel data formats	Mono8, BayerGR8		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.2W	2.2W	2.2W
Power consumption (PoE)	2.8W	Not supported	2.8W

Table 9: Model specific specification of GC2041C

Relative Response

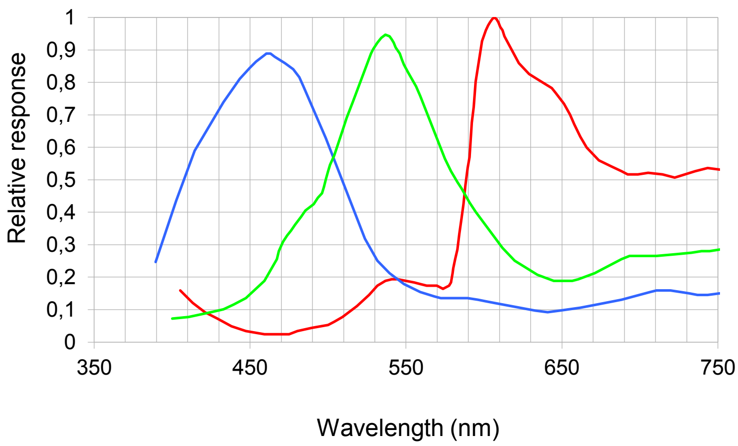


Figure 12: Relative response of GC2041 Color (from sensor datasheet)

2.2.3 GC2591M / GC2591C

	GC	GC-S90	GC-BL
Image Sensor	Aptina MT9P031		
Chromatics	Monochrome, Color		
Sensor type	CMOS		
Sensor resolution (H x W)	2592 x 1944		
Optical size	1/2.5"		
Pixel size (in µm)	2.2 x 2.2		
Analog gain (in dB)	0 to 23.5		
Shutter	Rolling		
Exposure time	36µs to 10s		
Max. frame rate (8Bit; in Hz)	14		
ADC bit depth	8 bit		
Pixel data formats	Mono8, BayerGR8		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.2W	2.2W	2.2W
Power consumption (PoE)	3.0W	Not supported	3.0W

Table 10: Model specific specification of GC2591

Relative Response

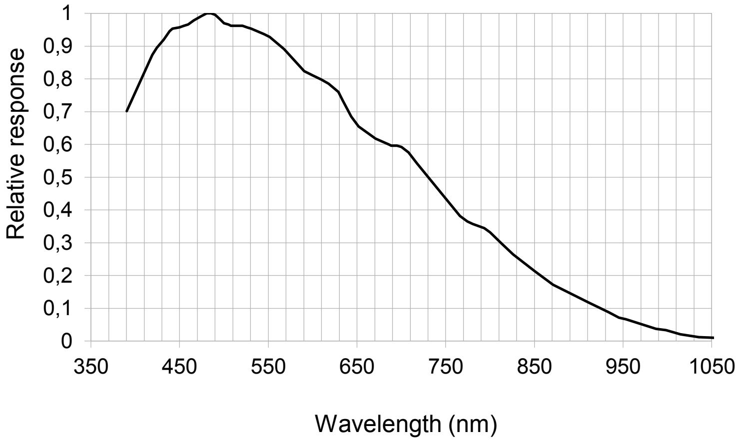


Figure 13: Relative response of GC2591 Monochrome (from sensor datasheet)

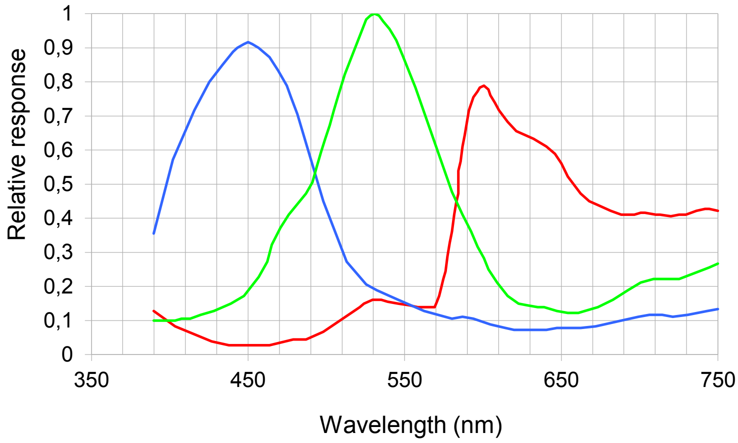


Figure 14: Relative response of GC2591 Color (from sensor datasheet)

2.2.4 GC3851M / GC3851C

	GC	GC-S90	GC-BL
Image Sensor	Aptina MT9J003		
Chromatics	Monochrome, Color		
Sensor type	CMOS		
Sensor resolution (H x W)	3856x2764	3848x2762	3856x2764
Optical size	1/2.3"		
Pixel size (in µm)	1.67 x 1.67		
Analog gain (in dB)	0 to 23.5		
Shutter	Rolling (free run), Global reset release (triggered)		
Exposure time	36µs to 10s		
Max. frame rate (8Bit; in Hz)	7		
ADC bit depth	8 bit		
Pixel data formats	Mono8, BayerGR8		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.5W	2.5W	2.5W
Power consumption (PoE)	3.2W	Not supported	3.2W

Table 11: Model specific specification of GC3851

Relative Response

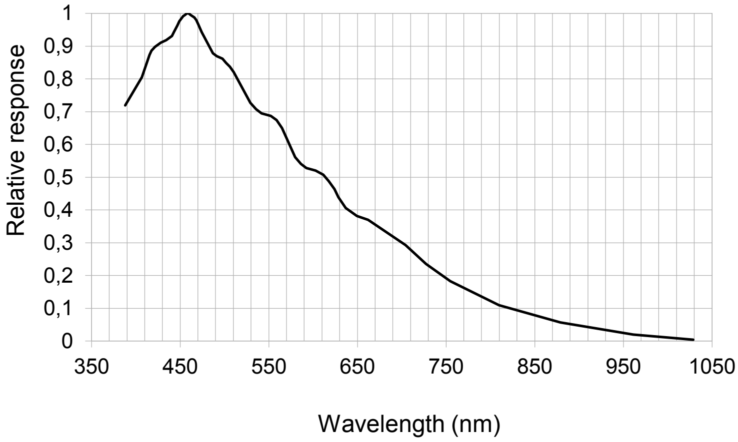


Figure 15: Relative response of GC3851 Monochrome (from sensor datasheet)

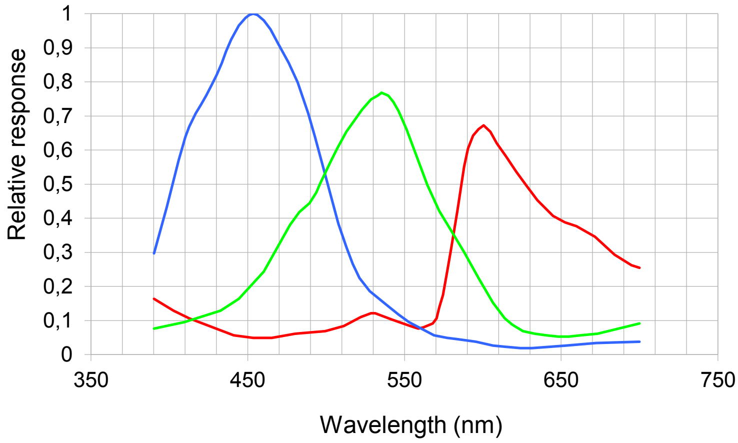


Figure 16: Relative response of GC3851 Color (from sensor datasheet)

2.2.5 GC651M / GC651C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX618		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	659x494	656x492	659x494
Optical size	1/4"		
Pixel size (in µm)	5.6 x 5.6		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	120		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.3W	2.3W	2.3W
Power consumption (PoE)	3.0W	Not supported	3.0W

Table 12: Model specific specification of GC651MC

Relative Response

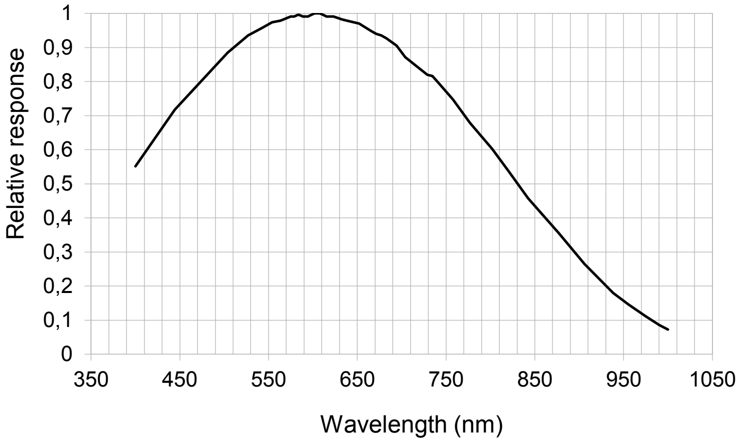


Figure 17: Relative response of GC651 Monochrome (from sensor datasheet)

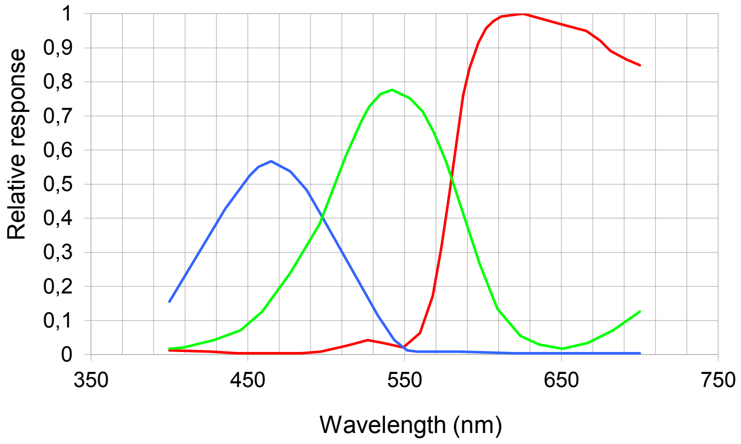


Figure 18: Relative response of GC651 Color (from sensor datasheet)

2.2.6 GC652M / GC652C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX424		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	659x494	656x492	659x494
Optical size	1/3"		
Pixel size (in µm)	7.4 x 7.4		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	97		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.6W	2.6W	2.5W
Power consumption (PoE)	3.2W	Not supported	3.2W

Table 13: Model specific specification of GC652

Relative Response

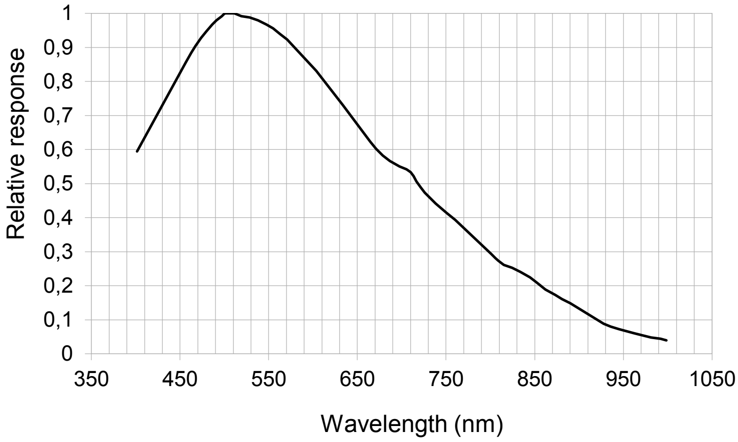


Figure 19: Relative response of GC652 Monochrome (from sensor datasheet)

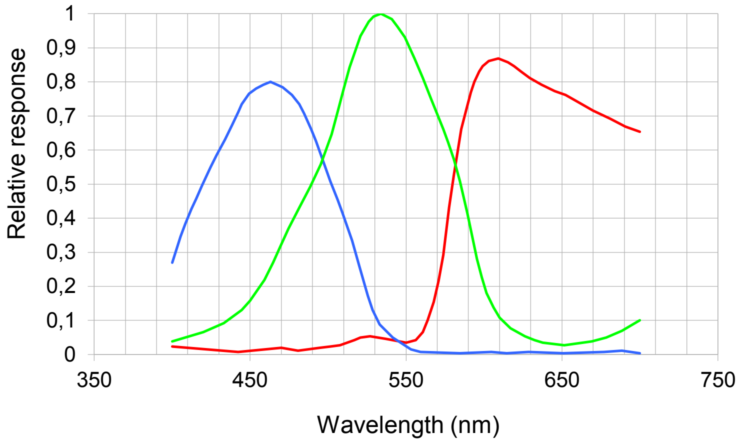


Figure 20: Relative response of GC652 Color (from sensor datasheet)

2.2.7 GC653M / GC653C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX414		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	659x494	656x492	659x494
Optical size	1/2"		
Pixel size (in µm)	9.9 x 9.9		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	97		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.6W	2.6W	2.5W
Power consumption (PoE)	3.2W	Not supported	3.2W

Table 14: Model specific specification of GC653

Relative Response

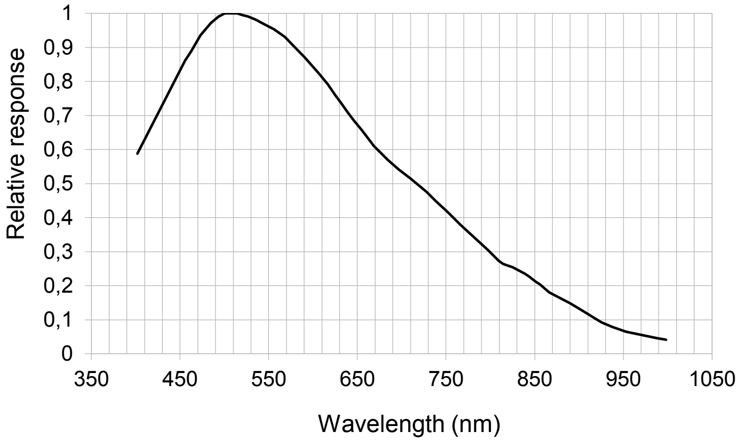


Figure 21: Relative response of GC653 Monochrome (from sensor datasheet)

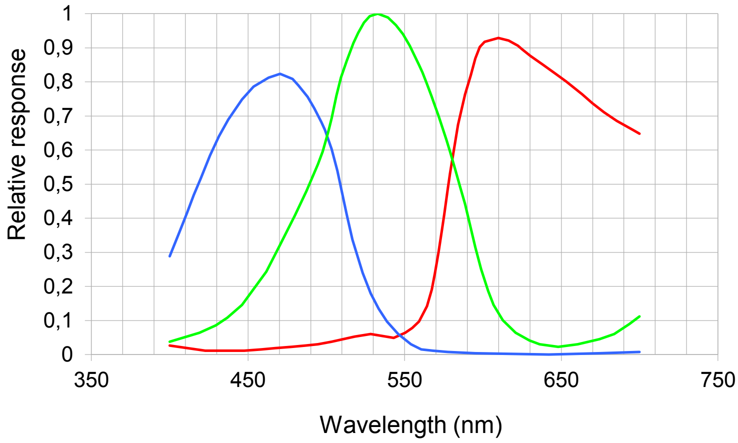


Figure 22: Relative response of GC653 Color (from sensor datasheet)

2.2.8 GC781M / GC781C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX415		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	782x582	776x580	782x582
Optical size	1/2"		
Pixel size (in µm)	8.3 x 8.3		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	68		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.6W	2.6W	2.5W
Power consumption (PoE)	3.2W	Not supported	3.2W

Table 15: Model specific specification of GC781

Relative Response

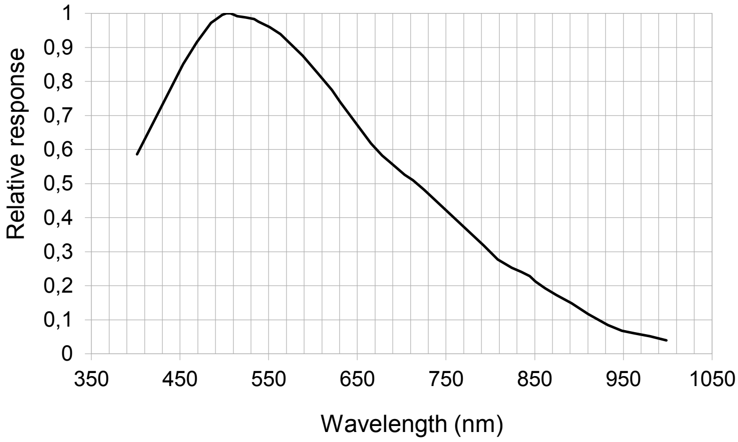


Figure 23: Relative response of GC781 Monochrome (from sensor datasheet)

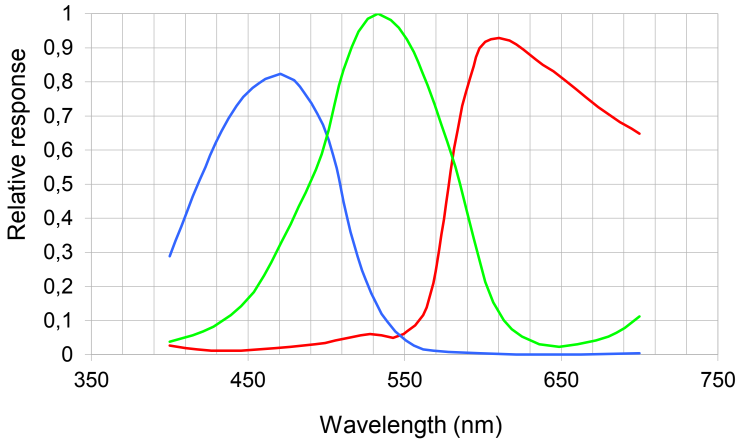


Figure 24: Relative response of GC781 Color (from sensor datasheet)

2.2.9 GC1031M / GC1031C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX204		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	1034x779	1032x778	1034x779
Optical size	1/3"		
Pixel size (in µm)	4.65 x 4.65		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	30		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.2W	2.2W	2.2W
Power consumption (PoE)	3.0W	Not supported	3.0W

Table 16: Model specific specification of GC1031

Relative Response

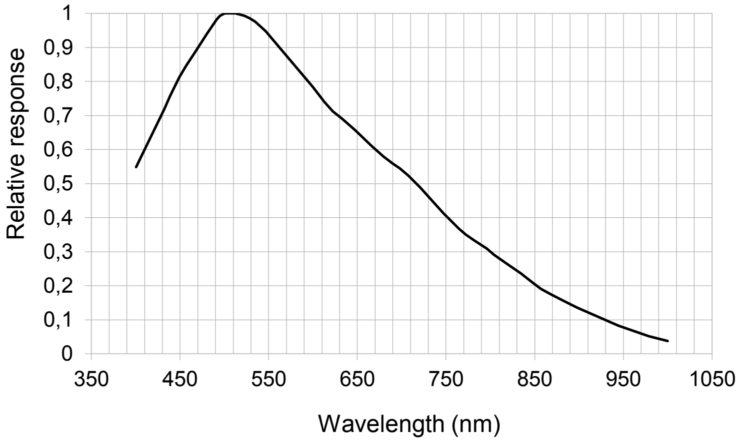


Figure 25: Relative response of GC1031 Monochrome (from sensor datasheet)

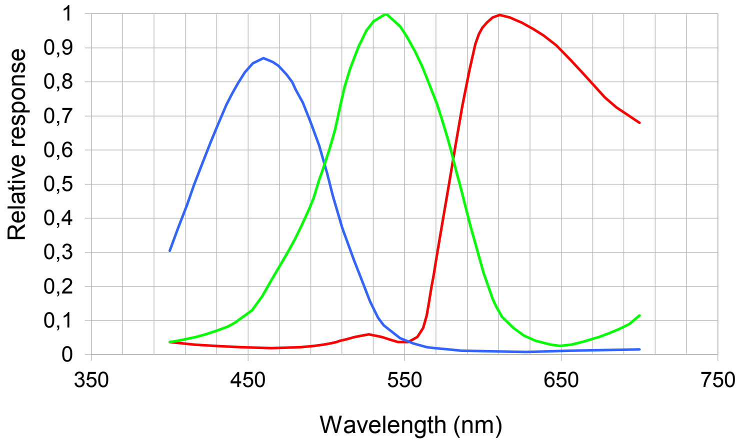


Figure 26: Relative response of GC1031 Color (from sensor datasheet)

2.2.10 GC1291M / GC1291C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX445		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	1296x966	1288x964	1296x966
Optical size	1/3"		
Pixel size (in µm)	3.75 x 3.75		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	30		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.5W	2.5W	2.5W
Power consumption (PoE)	3.2W	Not supported	3.2W

Table 17: Model specific specification of GC1291

Relative Response

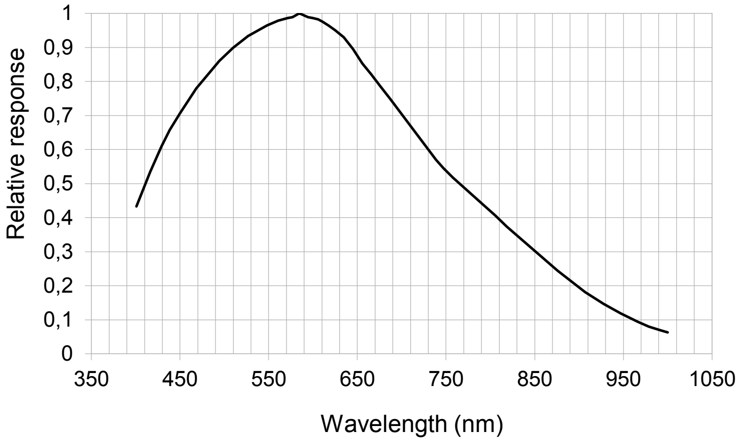


Figure 27: Relative response of GC1291 Monochrome (from sensor datasheet)

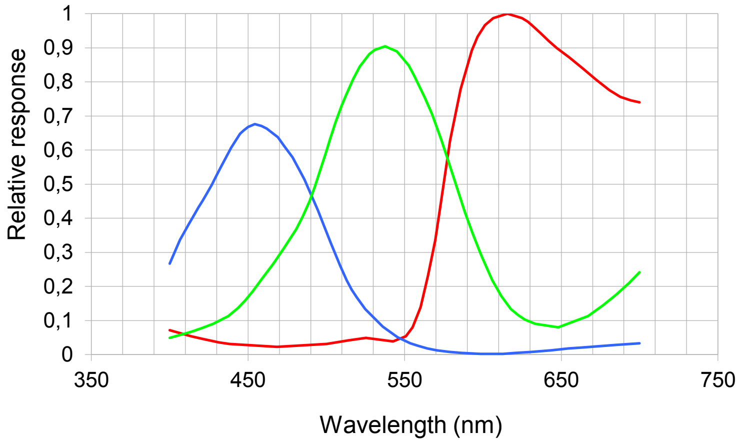


Figure 28: Relative response of GC1291 Color (from sensor datasheet)

2.2.11 GC1391M / GC1391C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX267		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	1392x1040	1384x1038	1392x1040
Optical size	1/2"		
Pixel size (in µm)	4.65 x 4.65		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	20		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.5W	2.5W	2.5W
Power consumption (PoE)	3.2W	Not supported	3.2W

Table 18: Model specific specification of GC1391

Relative Response

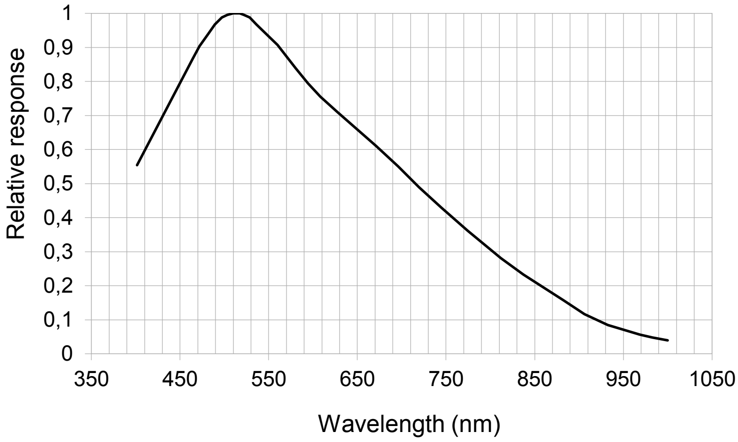


Figure 29: Relative response of GC1391 Monochrome (from sensor datasheet)

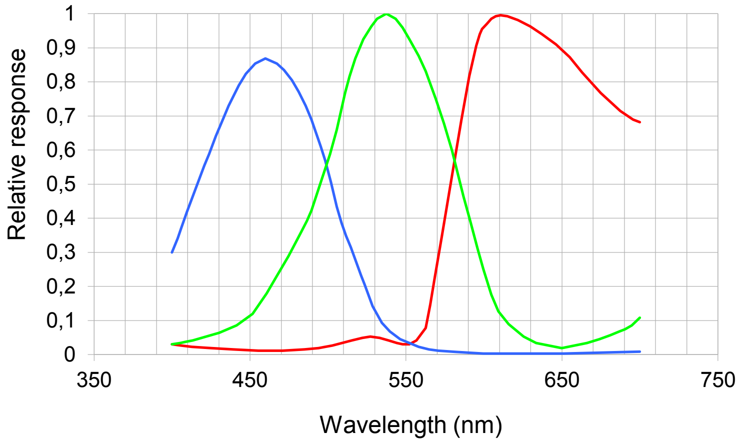


Figure 30: Relative response of GC1391 Color (from sensor datasheet)

2.2.12 GC1392M / GC1392C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX285		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	1392x1040	1384x1038	1392x1040
Optical size	2/3"		
Pixel size (in µm)	6.45 x 6.45		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	32		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.8W	2.8W	2.8W
Power consumption (PoE)	3.5W	Not supported	3.5W

Table 19: Model specific specification of GC1392

Relative Response

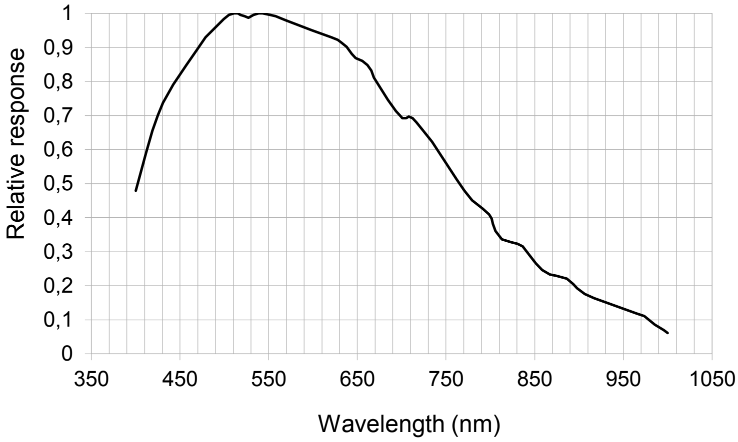


Figure 31: Relative response of GC1392 Monochrome (from sensor datasheet)

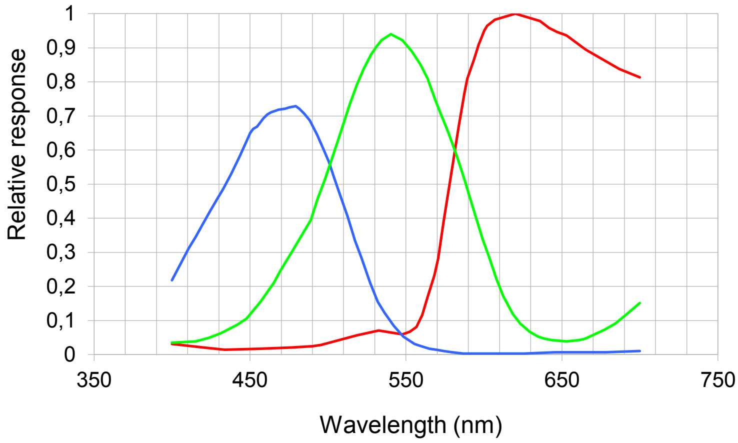


Figure 32: Relative response of GC1392 Color (from sensor datasheet)

2.2.13 GC1621M / GC1621C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX274		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	1628x1236	1624x1234	1628x1236
Optical size	1/1.8"		
Pixel size (in µm)	4.4 x 4.4		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	25		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	2.7W	2.7W	2.7W
Power consumption (PoE)	3.4W	Not supported	3.4W

Table 20: Model specific specification of GC1621

Relative Response

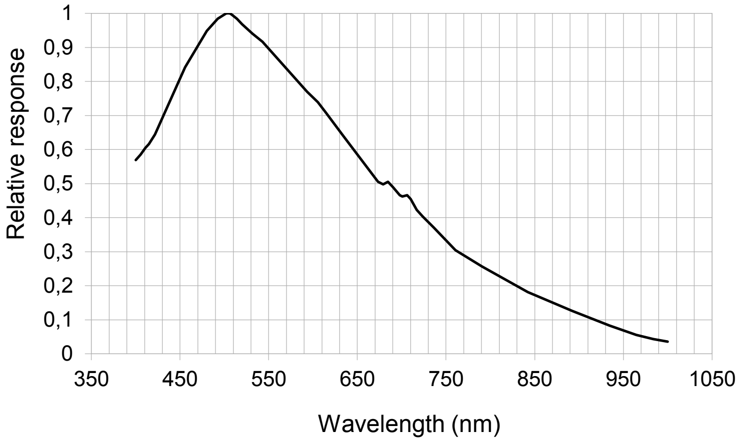


Figure 33: Relative response of GC1621 Monochrome (from sensor datasheet)

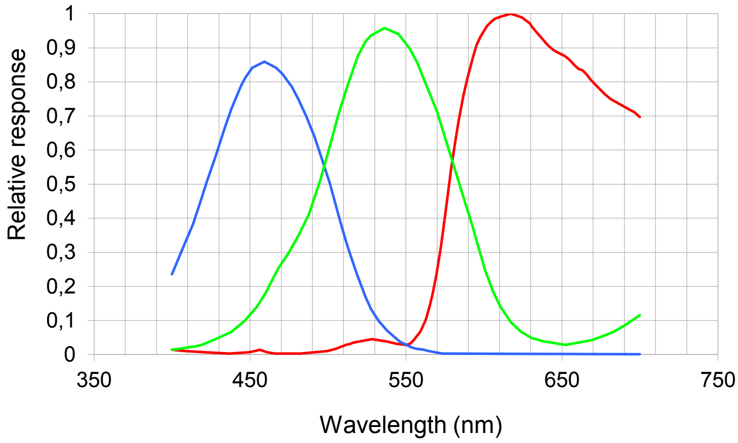


Figure 34: Relative response of GC1621 Color (from sensor datasheet)

2.2.14 GC2441M / GC2441C

	GC	GC-S90	GC-BL
Image Sensor	Sony ICX625		
Chromatics	Monochrome, Color		
Sensor type	CCD		
Sensor resolution (H x W)	2448x2058	2448x2056	2448x2058
Optical size	2/3"		
Pixel size (in µm)	3.45 x 3.45		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	15		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	3.6W	3.6W	3.6W
Power consumption (PoE)	4.5W	Not supported	4.5W

Table 21: Model specific specification of GC2441

Relative Response

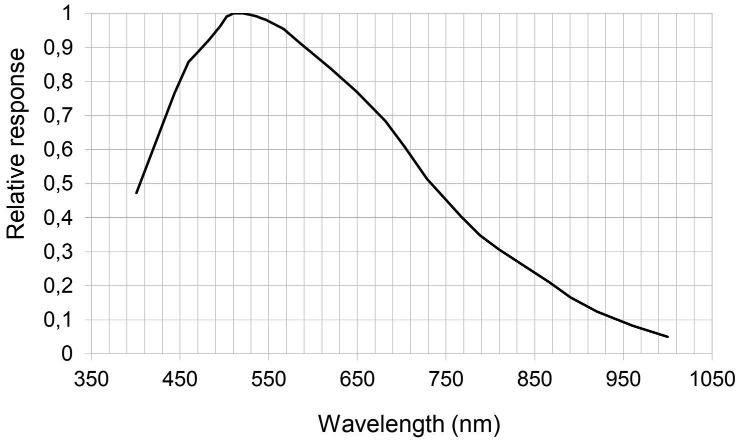


Figure 35: Relative response of GC2441 Monochrome (from sensor datasheet)

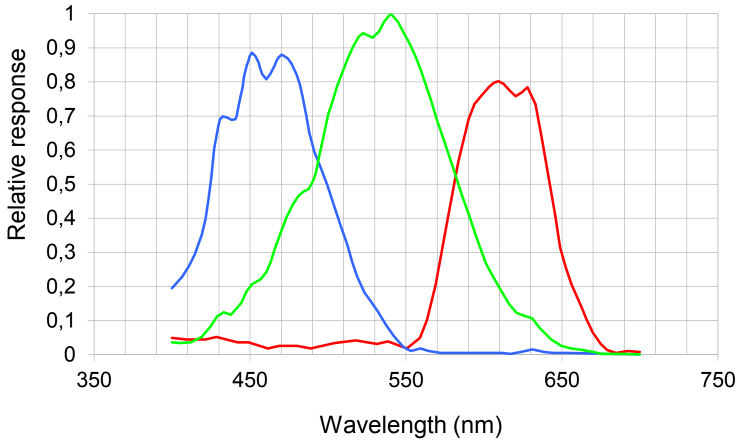


Figure 36: Relative response of GC2441 Color (from sensor datasheet)

2.2.15 GC1021M / GC1021C

	GC	GC-S90	GC-BL
Image Sensor	Truesense Imaging KAI-01050		
Chromatics	Monochrome, Color		
Sensor type	2 Tap CCD		
Sensor resolution (H x W)	1024 x 1024		
Optical size	1/2"		
Pixel size (in μm)	5.5 x 5.5		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10μs to 10s		
Max. frame rate (8Bit; in Hz)	61		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerGR8, BayerGR16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	3.4W	3.4W	3.4W
Power consumption (PoE)	4.1W	Not supported	4.1W

Table 22: Model specific specification of GC1021

Relative Response

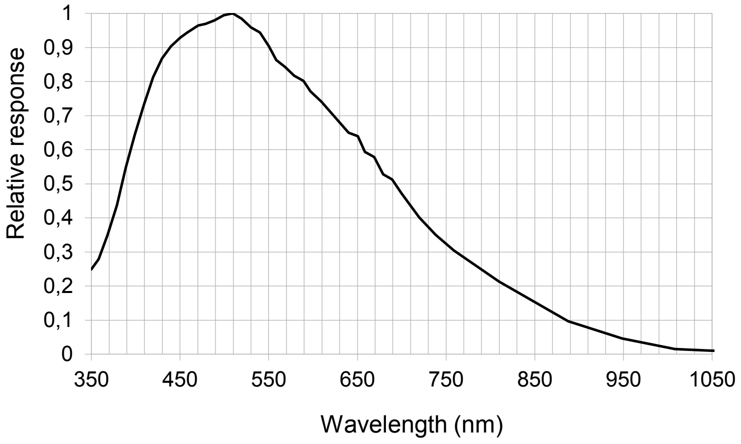


Figure 37: Relative response of GC1021 Monochrome (from sensor datasheet)

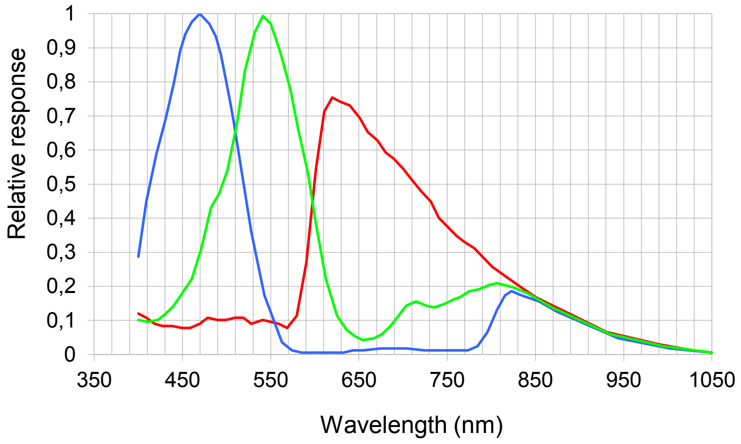


Figure 38: Relative response of GC1021 Color (from sensor datasheet)

2.2.16 GC1601M / GC1601C

	GC	GC-S90	GC-BL
Image Sensor	Truesense Imaging KAI-02050		
Chromatics	Monochrome, Color		
Sensor type	2 Tap CCD		
Sensor resolution (H x W)	1600 x 1200		
Optical size	2/3"		
Pixel size (in µm)	5.5 x 5.5		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	61		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerGR8, BayerGR16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	3.5W	3.5W	3.5W
Power consumption (PoE)	4.2W	Not supported	4.2W

Table 23: Model specific specification of GC1601

Relative Response

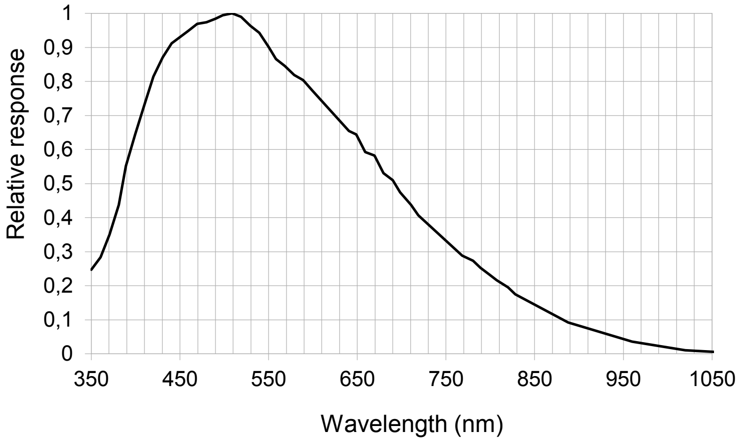


Figure 39: Relative response of GC1601 Monochrome (from sensor datasheet)

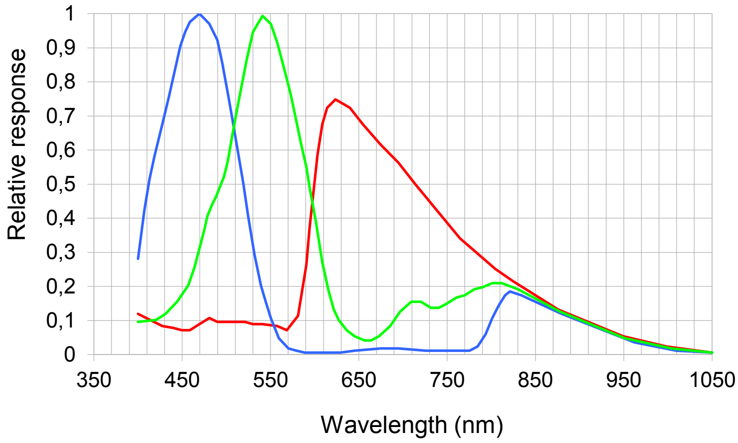


Figure 40: Relative response of GC1601 Color (from sensor datasheet)

2.2.17 GC1921M / GC1921C

	GC	GC-S90	GC-BL
Image Sensor	Truesense Imaging KAI-02150		
Chromatics	Monochrome, Color		
Sensor type	2 Tap CCD		
Sensor resolution (H x W)	1920 x 1080		
Optical size	2/3"		
Pixel size (in µm)	5.5 x 5.5		
Analog gain (in dB)	5.1 to 41.8		
Shutter	Progressive Scan		
Exposure time	10µs to 10s		
Max. frame rate (8Bit; in Hz)	33		
ADC bit depth	8 bit, 14 bit		
Pixel data formats (mono model)	Mono8, Mono16		
Pixel data formats (color model)	Mono8, Mono16, BayerGR8, BayerGR16		
Synchronization	Free run, external and software trigger (single shot, multi shot)		
Exposure control	Freely programmable via GigE Vision interface		
Power consumption (aux. / 12V)	3.6W	3.6W	3.6W
Power consumption (PoE)	4.3W	Not supported	4.3W

Table 24: Model specific specification of GC1921

Relative Response

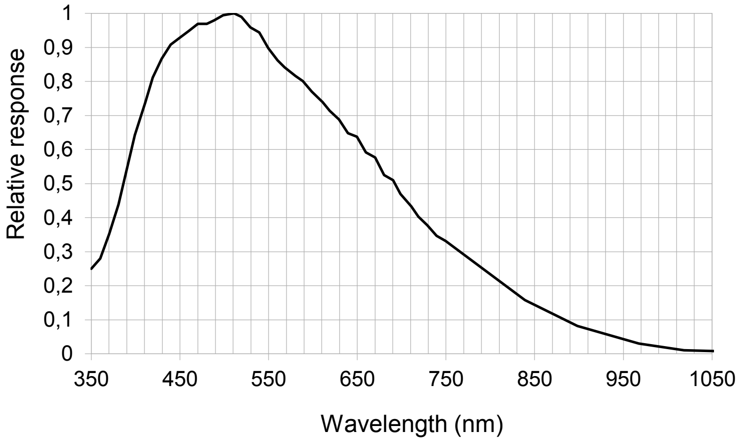


Figure 41: Relative response of GC1921 Monochrome (from sensor datasheet)

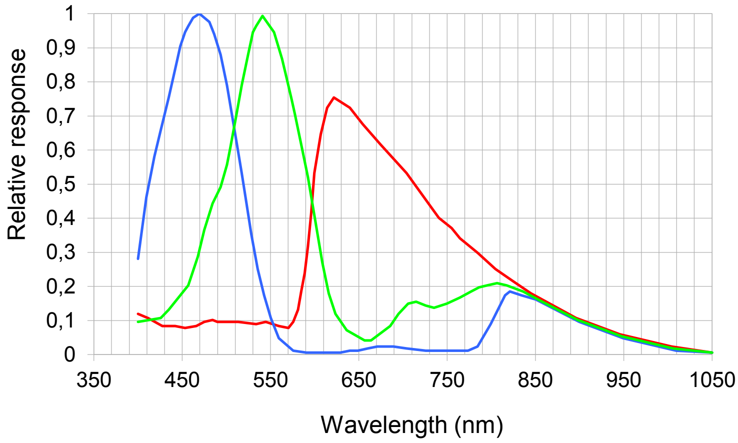


Figure 42: Relative response of GC1921 Color (from sensor datasheet)

2.2.18 GCP1941M / GCP1941C

	GCP
Image Sensor	Sony ICX674
Chromatics	Monochrome, Color
Sensor type	4 Tap CCD
Sensor resolution (H x W)	1936 x 1456
Optical size	2/3"
Pixel size (in µm)	4.54 x 4.54
Analog gain (in dB)	12 to 24
Shutter	Progressive Scan
Exposure time	10µs to 10s
Max. frame rate (8-/16Bit; in Hz)	36 / 17
ADC bit depth	8 bit, 14 bit
Pixel data formats (mono model)	Mono8, Mono16
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16
Synchronization	Free run, external and software trigger (single shot, multi shot)
Exposure control	Freely programmable via GigE Vision interface
Power consumption (aux. / 12V)	3.7W
Power consumption (PoE)	4.6W

Table 25: Model specific specification of GCP1941

Relative Response

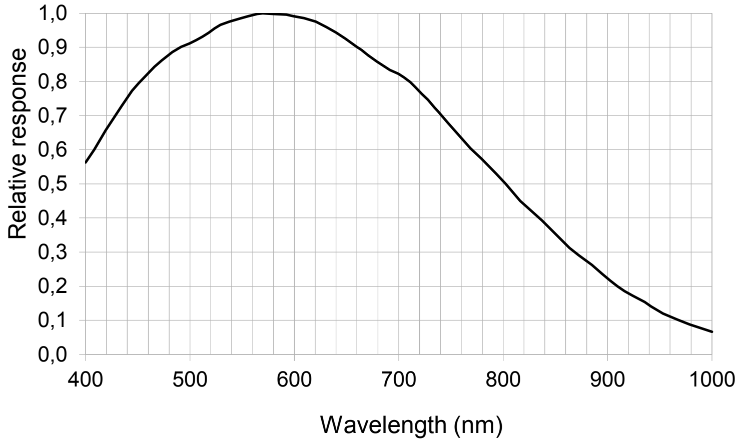


Figure 43: Relative response of GCP1941 Monochrome (from sensor datasheet)

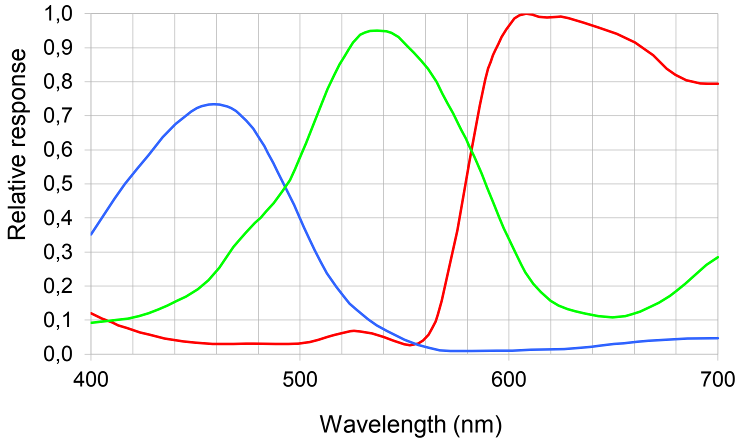


Figure 44: Relative response of GCP1941 Color (from sensor datasheet)

2.2.19 GCP2751M / GCP2751C

	GCP
Image Sensor	Sony ICX694
Chromatics	Monochrome, Color
Sensor type	4 Tap CCD
Sensor resolution (H x W)	2752 x 2208
Optical size	1"
Pixel size (in µm)	4.54 x 4.54
Analog gain (in dB)	12 to 24
Shutter	Progressive Scan
Exposure time	10µs to 10s
Max. frame rate (8-/16Bit; in Hz)	18 / 8
ADC bit depth	8 bit, 14 bit
Pixel data formats (mono model)	Mono8, Mono16
Pixel data formats (color model)	Mono8, Mono16, BayerGR8, BayerGR16
Synchronization	Free run, external and software trigger (single shot, multi shot)
Exposure control	Freely programmable via GigE Vision interface
Power consumption (aux. / 12V)	4.0W
Power consumption (PoE)	4.8W

Table 26: Model specific specification of GCP2751

Relative Response

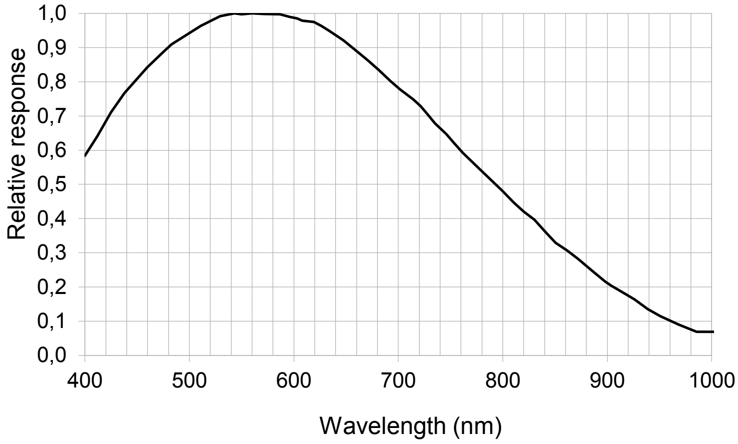


Figure 45: Relative response of GCP2751 Monochrome (from sensor datasheet)

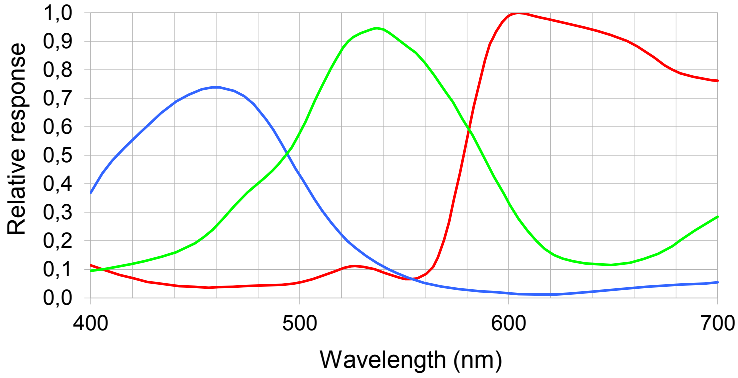


Figure 46: Relative response of GCP2751 Color (from sensor datasheet)

2.2.20 GCP3381M / GCP3381C

	GCP
Image Sensor	Sony ICX814
Chromatics	Monochrome, Color
Sensor type	4 Tap CCD
Sensor resolution (H x W)	3376 x 2704
Optical size	1"
Pixel size (in µm)	3.69 x 3.69
Analog gain (in dB)	12 to 24
Shutter	Progressive Scan
Exposure time	10µs to 10s
Max. frame rate (8-/16Bit; in Hz)	12 / 5
ADC bit depth	8 bit, 14 bit
Pixel data formats (mono model)	Mono8, Mono16
Pixel data formats (color model)	Mono8, Mono16, BayerRG8, BayerRG16
Synchronization	Free run, external and software trigger (single shot, multi shot)
Exposure control	Freely programmable via GigE Vision interface
Power consumption (aux. / 12V)	4.1W
Power consumption (PoE)	4.9W

Table 27: Model specific specification of GCP3381

Relative Response

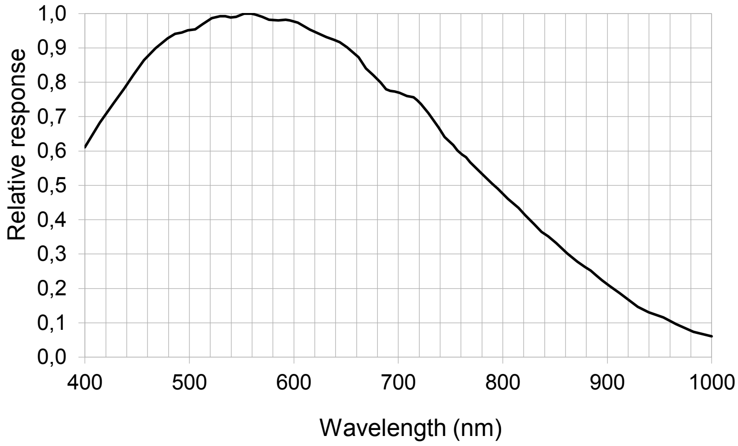


Figure 47: Relative response of GCP3381 Monochrome (from sensor datasheet)

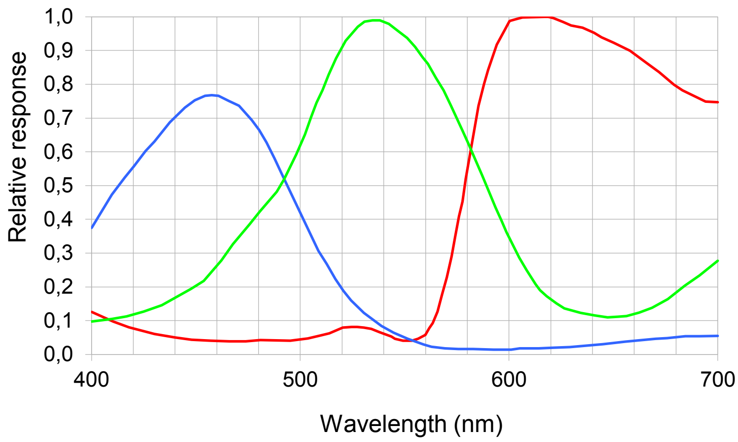


Figure 48: Relative response of GCP3381 Color (from sensor datasheet)

2.3 Physical Interfaces

All cameras are equipped with two physical interfaces - a circular Hirose jack providing the camera's power and digital IO lines and a RJ45 jack for 100/1000Mbit/s Ethernet communication. Figure 49 shows the general connecting scheme.

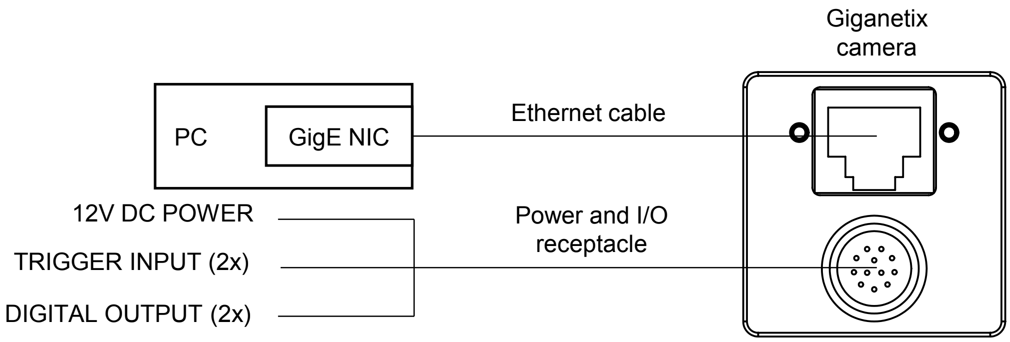


Figure 49: Connecting scheme

2.3.1 Ethernet Interface

The Ethernet Interface provides configuration access to the camera and is also used for image data transmission. The connector is a standardize RJ45 jack, assigned like shown in Table 28 below.

Ethernet Connector Type	RJ45, Ethernet 1000BaseT, 802.3 compliant	
Pin no.	**Signal**	**Description**
1	BI_DA+	Bi-directional pair +A
2	BI_DA-	Bi-directional pair -A
3	BI_DB+	Bi-directional pair +B
4	BI_DC+	Bi-directional pair +C
5	BI_DC-	Bi-directional pair -C
6	BI_DB-	Bi-directional pair -B
7	BI_DD+	Bi-directional pair +D
8	BI_DD-	Bi-directional pair -D

Table 28: Ethernet connector type and assignment

Status LEDs

The Ethernet connector provides a yellow and a green LED. The green LED indicates the status of the Ethernet link and its activity, while the yellow LED indicates the status of the camera. The description of the different statuses of these LEDs can be found in Table 29 and Table 30 below.

Green LED (Status)	Description
Off	No link
Solid on	Link on / Ethernet link exists
Blinking	Indicates ongoing Ethernet activity

Table 29: Ethernet Green LED status

Yellow LED (Status)	Description
Off	Not powered
Solid on	Power on / Status OK
One blink, then Off	No user firmware / Factory firmware active
Two blinks, then Off	Watchdog timer timeout error
Three blinks, then Off	User firmware data CRC error
Four blinks, then Off	Internal FPGA configuration error

Table 30: Ethernet Yellow LED status

Cabling Requirements

To connect the camera to a network, at least a straight UTP (Unshielded Twisted Pair) CAT5e cable needs to be used in environments with low or no EMI. In environments with higher EMI, a STP (Shielded Twisted Pair) CAT6 cable is recommended. The scheme for Straight-through patch cable is shown on Figure 50.

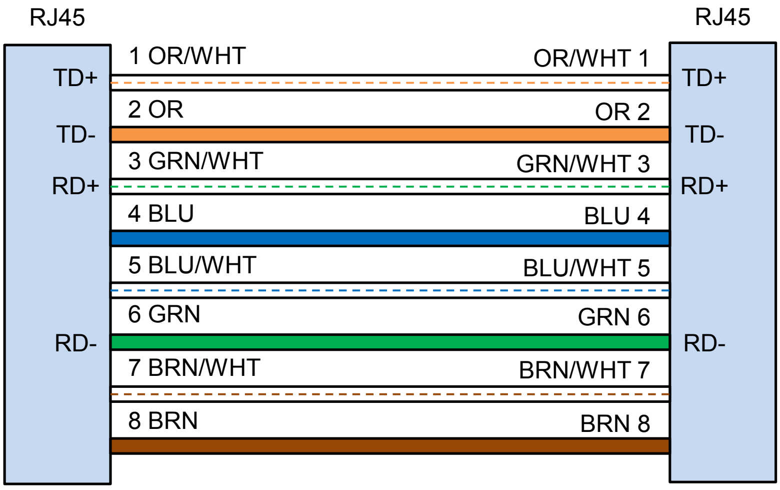


Figure 50: Straight-through cable scheme

2.3.2 Power and I/O-Interface

Beside the Ethernet interface for communication and data transmission, all cameras are equipped with a *Power and I/O-Interface*. Via this interface the cameras provide access to two digital input and two digital output lines, as well as their main power supply input. Depending on the type of camera there are two different kind of connector types used, shown in Table 31.

Model	Connector Type	Receptable
GC (standard housing)	12-pin Circular Hirose	HR10A-10P-12S
GC-S90 (angled 90° housing)	12-pin Circular Hirose	HR10A-10P-12S
GCP (standard housing)	12-pin Circular Hirose	HR10A-10P-12S
GC-BL (board level)	10-pin Molex Picoblade	53398-1071, 10-pins

Table 31: Power and I/O-interface connector type per model

2.3.2.1 12-pin Circular Hirose Connector

The housed Giganetix standard and 90° angled cameras are equipped with a 12-pin circular Hirose receptacle to provide access to the power interface as well as the input and output lines. Figure 51 shows the pin and connector orientation on the back of the camera housing, Table 32 shows the corresponding pin assignment.

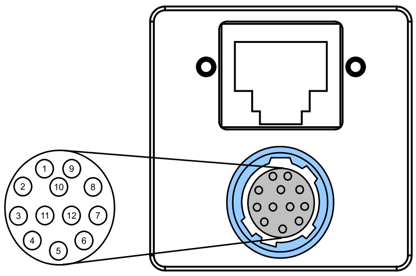


Figure 51: 12-pin circular Hirose receptacle - Pin and connector orientation

Pin no.	Signal
1	Power GND
2	DC power supply
3	Output 1 -
4	Output 1 +
5	Input 2 -
6	Input 2 +
7	Input 1 +
8	Input 1 -
9	Output 2 -
10	Output 2 +
11	Input 1 +
12	Input 1 -

Table 32: 12-pin circular Hirose receptacle - Pin assignment

Note

The 12-pin connector on the camera is a Hirose receptacle and can be used with a HR10A-10P-12S or equivalent.

Caution

Only cameras with PoE provide a polarity protection on the power input circuit; voltage reversal on models without PoE will damage the camera!

Cabling Requirements

A single 12-pin Hirose receptacle is used to power the camera and provide access to its input and output lines. When assembling the 12 pin Hirose connector on one side of the cable, care must be taken to follow the pin arrangement shown in Table 32 (determining pin 1 from the supplied drawing is critical). It is recommended to use a shielded twisted pair cable to avoid EMI, the maximum length should not exceed 10m.

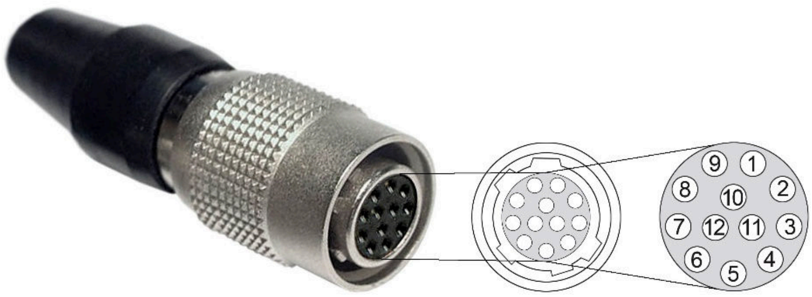


Figure 52: Hirose 12-pin plug connector

Note The 12 pin connector for the cable is a Hirose plug HR10A-10P-12S(73) (or equivalent).

Caution An incorrect pin alignment or connector can damage the camera.

2.3.2.2 10-pin Molex Picoblade Connector

The board level Giganetix cameras (GC-BL) are equipped with a 10-pin Molex Picoblade receptacle to provide access to the power interface as well as the input and output lines. Figure 52 shows the pin and connector orientation on the back of the camera housing, Table 33 shows the corresponding pin assignment.

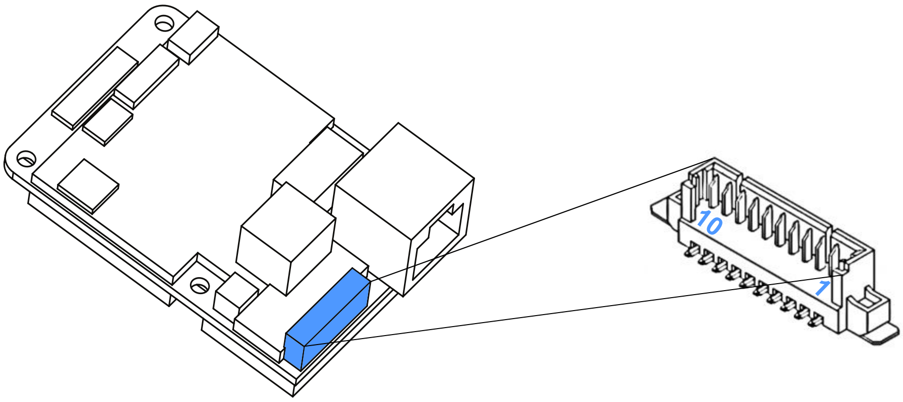


Figure 53: 10-pin Molex Picoblade receptacle - Pin and connector orientation

Pin no.	Signal
1	DC power supply
2	Power GND
3	Output 2 +
4	Output 2 -
5	Output 1 +
6	Output 1 -
7	Input 1 +
8	Input 1 -
9	Input 2 +
10	Input 2 -

Table 33: 12-pin circular Hirose receptacle - Pin assignment

Note: The 10-pin connector on the camera mainboard is a Molex Picoblade 53398-1071 with 10-pins.

2.3.2.3 Input Lines (Electrical Specifications)

All cameras are equipped with two physical input lines designated as input line 1 and input line 2. The input lines are accessed via the power and I/O interface receptacle on the back of the camera. Each input line is opto-isolated. Table 34 shows the operational limits of the trigger input lines, while Figure 54 shows their electrical scheme.

Description	Limits
Recommended operating voltage	+0 to +24 VDC
Voltage level representing logical 0	+0 to +1.4 VDC
Region where the transition threshold occurs; the logical state is not defined in this region	> +1.4 to +2.2 VDC
Voltage level representing logical 1	> +2.2 VDC
Absolute maximum; the camera may be damaged when the absolute maximum is exceeded	+30.0 VDC

Table 34: Electrical specification for trigger input (operational limits)

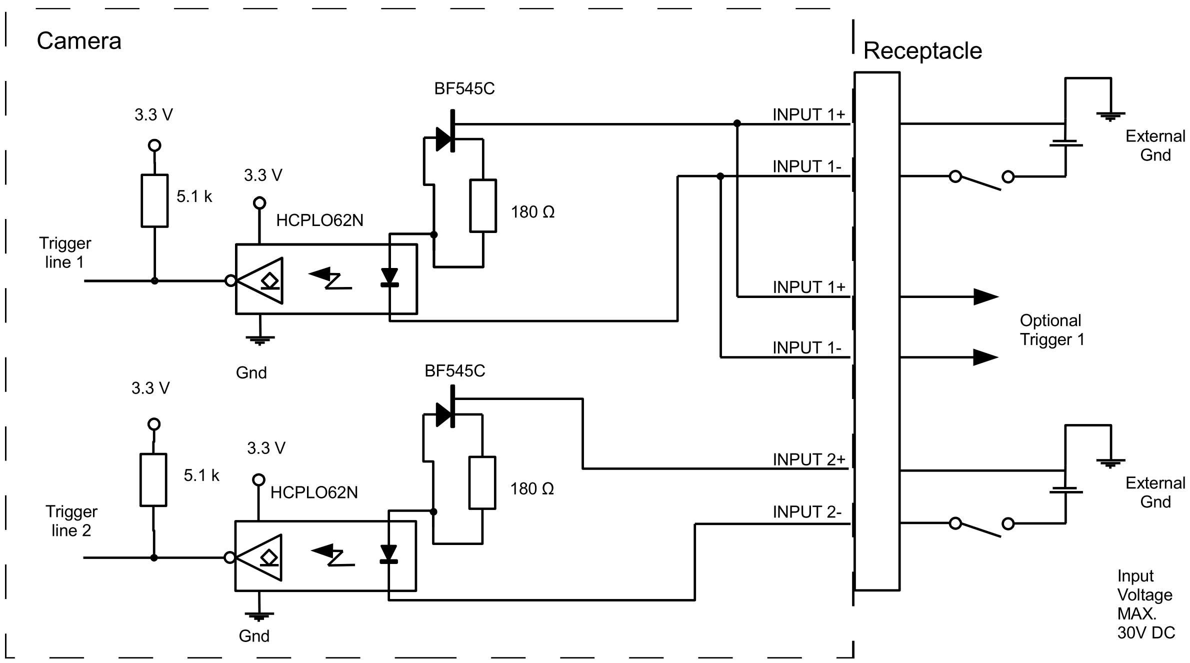


Figure 54: Trigger input scheme

2.3.2.4 Output Lines (Electrical Specifications)

All cameras are equipped with two physical output lines, designated as output line 1 and output line 2. The output lines are accessed via the power and I/O interface receptacle, Table 35 shows the operational limits of the trigger input lines, Figure 55 shows their electrical scheme. Each output line is opto-isolated.

Description	Limits
The I/O output may operate erratically	< +3.3 VDC
Recommended operating voltage	+3.3 to +24 VDC
Absolute maximum; the camera may be damaged if the absolute maximum is exceeded	+30.0 VDC
The maximum current surge for outputs	25 mA

Table 35: Electrical specification for digital output

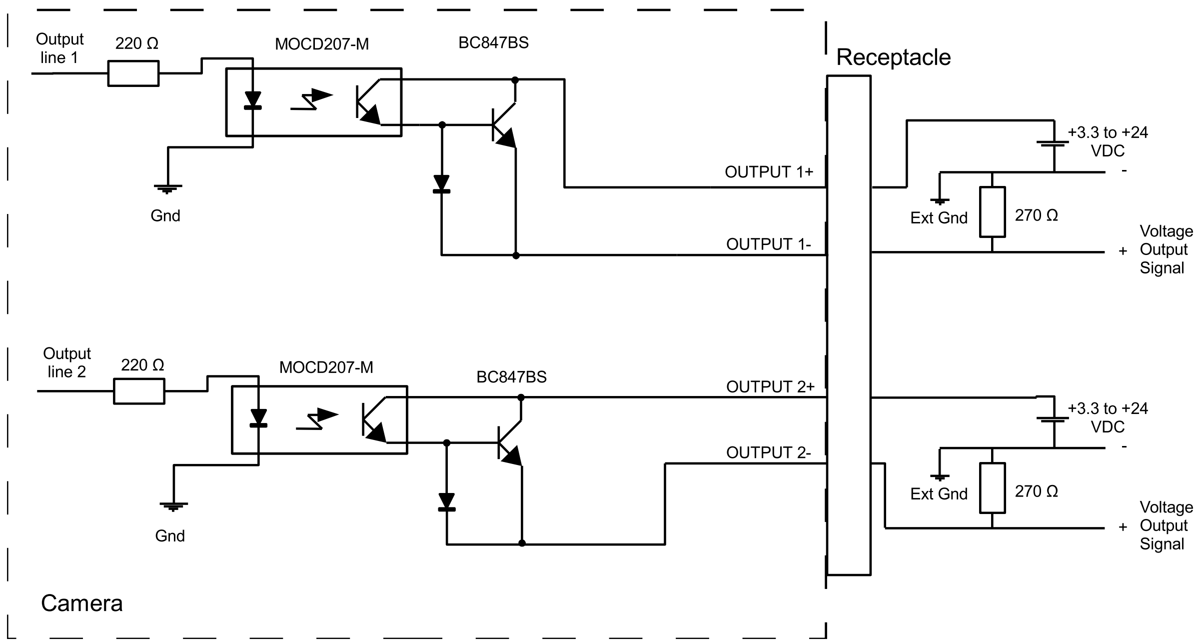


Figure 55: Digital output scheme

2.3.3 Temperature Specification and Heat Dissipation

The temperature specification given for storing and operation of all devices are measured at any location of the camera's housing. If the camera is delivered without a housing, the specified range refers to the direct ambient temperature of the board-set, at any location. In operation it must be ensured that the internal heat generation of the camera is dissipated sufficiently to make the device or its environment not exceed the specified borders. The camera will steadily heat up in the first hour of operation and should be monitored.

Beside the risk of damage, a too high camera temperature also decreases the image quality of the sensor significantly. The thermal noise generated in silicon based sensors raises exponentially with the temperature, hereby the useful signal falls rapidly.

As every application and environment has its own characteristics, SMARTEK Vision can only suggest general strategies to keep the camera's temperature low:

- Mount housed cameras with at least one complete side of the housing to a massive heat conductive material (e.g. aluminum); make sure that the whole surface is constantly in touch
- Active cooling of the camera by a fan will significantly decrease the temperature
- Keep the ambience temperature as low as possible

Board level cameras:

- If mounted into another closed device, make sure to offer a constant heat exchange by e.g. an air flow
- Additional active / passive heat sinking of the critical components (Sensor Head, Flash, FPGA, DDR, Ethernet Physical, PoE driver etc.) allows for higher ambient temperatures (at own risk)

Example

Figure 56 gives an example of the thermal behavior of a Giganetix camera mounted to different heat conductors, described in Table 36. The used camera is a GC1921M with a 2 Tap Truesense Imaging sensor, which was chosen as one with the highest power consumption (3.6 Watts) in the Giganetix lineup.

Color	Label	Description
—-	*Not mounted*	Camera is placed on a material with a very low heat conductivity (plastic); the main heat dissipation occurs over the surrounding air
—-	*Aluminum (loose)*	Camera is placed loose on a construction profile (150x70x30 mm) of a material with a very good heat conductivity (aluminum)
—-	*Aluminum (well mounted)*	Camera is well mounted on a construction profile (150x70x30 mm) of a material with a very good heat conductivity (aluminum)

Table 36: Description of the curves in Figure 56

In each setup, the camera and its heat conductor are exposed to the environment temperature of 22.5°C, until all match (1). As soon as the camera is powered (2) it starts to heat immediately (3) and reaches its maximum after around one hour (4). The difference in temperature between the sample setups is significantly; the camera which is not mounted to any heat conductor is with 50.4°C after one hour in an environmental temperature of 22.5°C already slightly over specification. With a small aluminum heat conductor the camera temperature drops about 12 to 15°C.

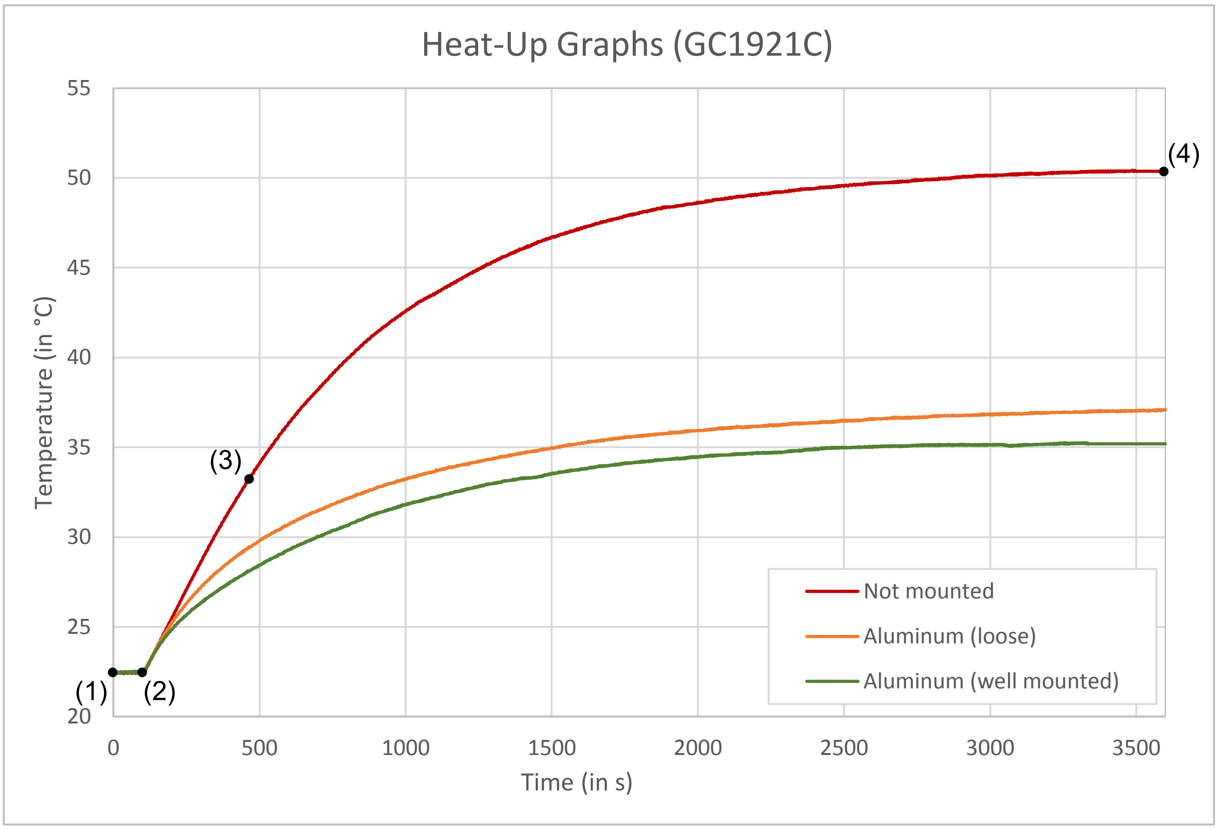


Figure 56: Example of heat up behavior of a camera with different thermal connections

2.3.4 IR-Cut Filter

The spectral sensitivity of the CCD/CMOS image sensors extends into the near-infrared range, what can result in for the human eye unnatural-looking images on color camera models. To allow an accurate reproduction of images from color image sensors, IR-cut filters are used.

IR-cut filters are short pass filters that block near infrared light of wavelengths longer than approximately 660nm and pass visible light. All color camera models are equipped with an IR-cut filter as standard, monochrome models do not have an IR-cut filter installed by default. Figure 57 below shows the transmission curve of the filter used in the Giganetix camera family.

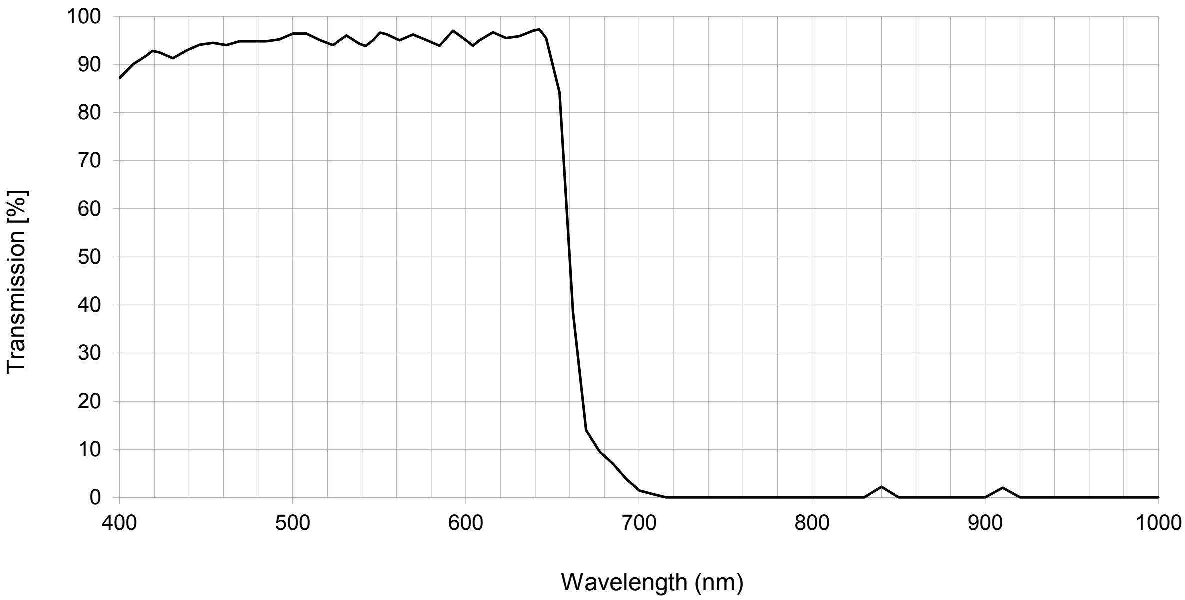


Figure 57: IR-cut filter specification

2.3.5 Ingress Protection Class

The camera housing fulfills the *Ingress Protection Class* of IP40. It is protected against solid objects with a diameter larger than 1 mm (tools, wires, and small wires) and has no protection against liquids.

2.4 Declarations of Conformity

2.4.1 CE

Manufacturer:	Smartek d.o.o Bana Josipa Jelacica 22c HR-40000 Čakovec Croatia
Product:	Digital Gigabit Ethernet Camera
Type Family:	Giganetix Standard, Giganetix S90 Version, Giganetix Plus
Type of Equipment:	GC1281M, GC2041C, GC2591M, GC2591C, GC3851M, GC3851C, GC651M, GC651C, GC652M, GC652C, GC653M,GC653C, GC781M, GC781C, GC1031M, GC1031C, GC1391M, GC1391C, GC1392M, GC1392C, GC1621M, GC1621C, GC2441M,GC2441C, GC1021M, GC1021C, GC1291M, GC1291C, GC1601M,GC1601C, GC1921M, GC1921C, GCP1941M, GCP1941C, GCP2751M, GCP2751C, GCP3381M, GCP3381C

This equipment is in compliance with the essential requirements and other relevant provisions of the following EC directives:

Reference No.	Title:
89/336/EEC, 92/31/EEC	Electromagnetic Compatibility (EMC directive)

Following standards or normative documents:

EN 55022:1994 Class A + A1:1995 + A2:1997,
EN 61326:1997 Class A + A1:1998 + A2:2001 + A3:2003,
EN 55024:1998 + A1:2001 + A2:2003

The equipment specified above was tested conforming to the applicable Rules under the most accurate measurement standards possible, and that all the necessary steps have been taken and are in force to assure that production units of the same product will continue comply with the requirements.

Damir Dolar

Dipl. Ing. Hardware Engineer

Smartek d.o.o.

2.4.2 FCC

Manufacturer:	Smartek d.o.o Bana Josipa Jelacica 22c HR-40000 Čakovec Croatia
Product:	Digital Gigabit Ethernet Camera
Type Family:	Giganetix Standard, Giganetix S90 Version, Giganetix Plus
Type of Equipment:	GC1281M, GC2041C, GC2591M, GC2591C, GC3851M, GC3851C, GC651M, GC651C, GC652M, GC652C, GC653M,GC653C, GC781M, GC781C, GC1031M, GC1031C, GC1391M, GC1391C, GC1392M, GC1392C, GC1621M, GC1621C, GC2441M,GC2441C, GC1021M, GC1021C, GC1291M, GC1291C, GC1601M,GC1601C, GC1921M, GC1921C, GCP1941M, GCP1941C, GCP2751M, GCP2751C, GCP3381M, GCP3381C
Directive:	FCC Part 15, Class A

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment under FCC rules

Damir Dolar

Dipl. Ing. Hardware Engineer

Smartek d.o.o.

2.4.3 RoHS

Manufacturer:	Smartek d.o.o Bana Josipa Jelacica 22c HR-40000 Čakovec Croatia
Product:	Digital Gigabit Ethernet Camera
Type Family:	Giganetix Standard, Giganetix S90 Version, Giganetix Plus
Type of Equipment:	GC1281M, GC2041C, GC2591M, GC2591C, GC3851M, GC3851C, GC651M, GC651C, GC652M, GC652C, GC653M,GC653C, GC781M, GC781C, GC1031M, GC1031C, GC1391M, GC1391C, GC1392M, GC1392C, GC1621M, GC1621C, GC2441M,GC2441C, GC1021M, GC1021C, GC1291M, GC1291C, GC1601M,GC1601C, GC1921M, GC1921C, GCP1941M, GCP1941C, GCP2751M, GCP2751C, GCP3381M, GCP3381C

This equipment is in compliance with the essential requirements and other relevant provisions of the following RoHS Directive 2002/95/CE.

Damir Dolar

Damir Dolar

Dipl. Ing. Hardware Engineer

Smartek d.o.o.

3 Smartek GigEVisionSDK Library

The SMARTEK Vision GigEVisionSDK provides a set of tools, guides and samples, useful for the configuration and image acquisition from GigE Vision cameras, as well as the integration into own software applications. The GigEVisionSDK library consists of 4 basic parts:

- **Smartek Filter Driver** - SMARTEK Vision provides its own filter driver to ensure optimal performance of the digital camera. This driver is compliant to the GigE Vision standard. It separates incoming packets containing image data from other traffic on the network, optimizing the image data flow from the camera to the software.
- **GigEVisionClient** - The GigEVisionClient is an as binary and source available sample application, which contains and utilizes the whole function set available by the GigEVisionSDK API in an intuitive graphical user interface. Besides displaying images grabbed from the cameras, it provides graphical access to e.g. multiple cameras, their configuration and available post processing functions.
- **GigEVisionSDK API** - The GigEVisionSDK offers an application programming interface (API) for for Gigabit Ethernet Vision (GigE Vision) cameras. It supports the programming languages C/C++, Delphi, C# and VB .NET, and allows an easy integration of a SMARTEK Vision camera in own software applications.
- **ImageProc API** - The ImageProc API extends the basic camera functionality, provided by the GigEVisionSDK API, by color and post processing functions like e.g. debayering, gamma, look-up table (LUT) and color correction algorithms. All programming languages supported by the GigEVisionSDK API are supported by the ImageProc API as well.

3.1 Supported Operating Systems

The SMARTEK Vision GigEVisionSDK has been created to support Microsoft Windows as well as Linux operating systems. For Microsoft Windows, one software installer supports all versions and system architectures (32 or 64 Bit). The GigEVisionSDK for Linux is available in versions for Debian and RPM based packet managers, separately for 32 and 64 Bit. Table 37 contains a list of the supported operating systems and the appropriate installation package.

	Operating System	32 Bit	64 Bit	SDK Package
Microsoft	Windows XP	✓	✓	Windows Executable
	Windows Vista	✓	✓	
	Windows 7	✓	✓	
	Windows 8	✓	✓	
	Windows 8.1	✓	✓	
Linux	DEB based (Debian, Ubuntu, Knoppix)	✓	✓	32Bit.deb / 64Bit.deb
	RPM based (Fedora, Red Hat, SUSE)	✓	✓	32Bit.rpm / 64Bit.rpm

Table 37: Supported operating systems and installation packages

3.2 (Un-)Installing the GigEVisionSDK on Microsoft Windows and Linux

QuickStart and Installation guides for Microsoft Windows and Linux operating systems can be downloaded separately from the SMARTEK Vision webpage:

www.SMARTEKvision.com/downloads.php

The uninstallation on Microsoft Windows can be started by removing the software in *Programs and Features* in the Microsoft Windows *Control Panel*.

3.3 Unattended Installation on Microsoft Windows Operating Systems

In cases where the GigEVisionSDK needs to be included into user's own installer it is possible to install the package in silent mode. This way it is possible to install the package without any graphical output and user interactions.

To run the installation silently, execute the binary from the command prompt as Administrator, with the following flags (in one line):

```
SMARTEK_Vision_GigEVisionSDK_Vxxxx.exe    /VERYSILENT
/SUPPRESSMSGBOXES
/NORESTART
/TYPE="minimal"
```

There are three types of installations that can be performed:

1. `/TYPE="minimal"` - minimal installation (binaries only)
2. `/TYPE="compact"` - compact installation (binaries, headers, docs and samples)
3. `/TYPE="full"` - full installation (binaries, headers, docs, samples and sources)

3.4 Manual Filter Driver Installation / Uninstallation

If the SMARTEK Vision GigEVision Filter Driver needs to be installed manually, it can be installed independently of the GigEVisionSDK by executing a batch script (*.bat), located in the SDK's installation directory after successfully installing the GigEVisionSDK.

This is for example the case if the first instance of the GigEVisionClient starts without the filter driver, showing the message in Figure 58. Additionally a warning message in the top bar of GigEVisionClient is displayed - *"Warning: Smartek Filter Driver not loaded"*.

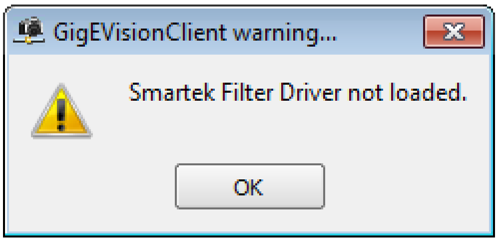


Figure 58: Warning: Smartek Filter Driver not loaded

The batch scripts can be found in a subfolder of the installation directory. By default the GigEVisionSDK is installed into the following folder:

```
C:\Program Files\SMARTEKvision\GigEVisionSDK\..
```

The driver specific files are located in the following subfolder:

```
..\drivers\FilterDriver\..
```

The driver is being installed by executing ***GigEVDrvInstall.bat***, uninstalled by executing ***GigEVDrvUninstall.bat***

3.5 GigEVisionClient

The GigEVisionClient is a Qt-based open-source application installed along with the GigEVisionSDK. It utilizes and demonstrates the major function set available by the API in an intuitive graphical user interface and is capable of acquiring and controlling single or multiple GigE Vision compliant cameras.

After the installation of the GigEVisionSDK the GigEVisionClient can be started by the appropriate shortcut in the Microsoft Windows Start menu (All Programs ⇒ SMARTEK Vision). The binaries can be found within the installation directory, usually located at:

```
C:\Program Files\SMARTEKvision\GigEVisionSDK\bin\
```

The source code is located at:

```
C:\Program Files\SMARTEKvision\GigEVisionSDK\src\GigEVisionClient
```

3.5.1 Graphical User Interface (GUI)

Figure 59 shows the default GUI elements of the GigEVisionClient.

- **Menu bar** - always on top of the application. It provides access to all functionalities available on the toolbar. Also main dialogs within the GigEVisionClient can be switched on or off under the entry Control. Several dialogs are disabled by default and can be activated manually:
  - *Preview* - separate displays for each connected camera
  - *Device Property Info* - GenICam attributes of the selected device property
  - *API Settings* - access to configuration settings of API and driver
  - *Histogram* - display a histogram for the currently selected device
  - *Log* - display the API log
- **Toolbar** - enables quick access to basic functions of the camera (find, connect, disconnect, IP setup), image handling (open, save, zoom etc.), GUI handling (save GUI arrangement, open, reset GUI to default etc.).
- **Device list dialog** - lists all GigE Vision compliant devices found on the network and its connection status. It further acts as the camera selector.
- **Device properties dialog** - gives access to all features (GenICam) supported by the device.
- **Image Processing properties dialog** - gives access to the parameterizations settings of the image processing algorithms.
- **Info bar** - displays information like image size, frame rate, data transfer rate, cursor position and pixel value at cursor position.
- **Image display window** - main window for displaying a single image or video stream.

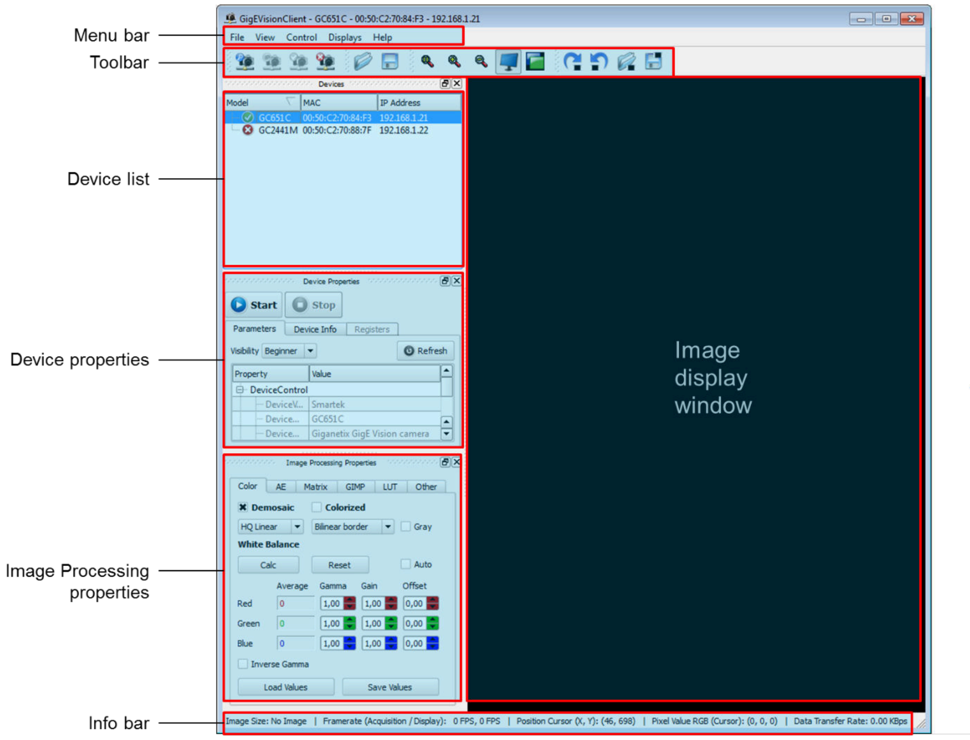


Figure 59: GigEVisionClient Graphical User Interface (GUI)

Refer to Figure 60 for a full description of all GUI elements on the toolbar.

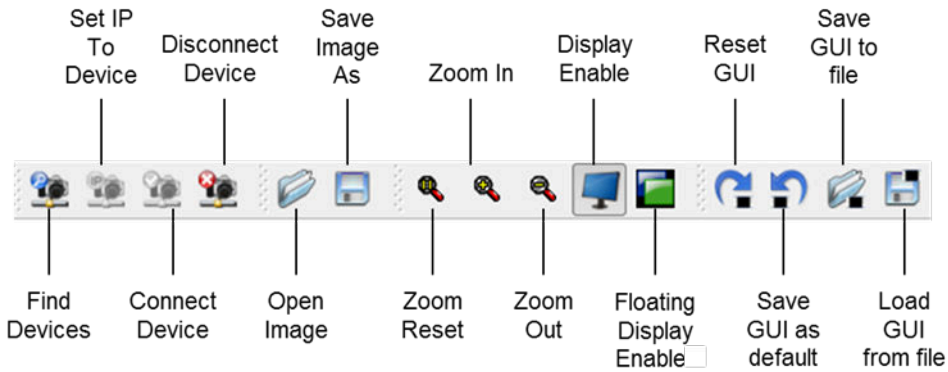


Figure 60: Toolbar description

Due to the possibility that all the dialogs within the GigEVisionClient are dockable, the user can set his own user interface as default or save it to a file, so that his own GUI arrangement can be loaded to the GigEVisionClient installed on other machines. The GUI save and reset features are accessed through the menu bar or the toolbar, as shown in Figure 60.

Note The Floating Display feature allows the user to arrange different image displaying windows for each camera's video stream on the screen.

3.5.2 Acquire Images from Camera(s)

In this section a step-by-step guide will be introduced, showing how the user can start the image acquisition from a camera using the SMARTEK Vision GigEVisionClient.

3.5.2.1 Device Enumeration

After the GigEVisionClient is started, it automatically searches for GigE Vision compliant devices connected to the network. All found devices are listed in the device list dialog. If the required camera is attached or powered-up subsequent and is not shown in the list, the user can manually update the list and search for devices.

To search for devices within the network(s) the computer is connected to, click the *Find Devices* icon in the *Toolbar*, shown in Figure 61.

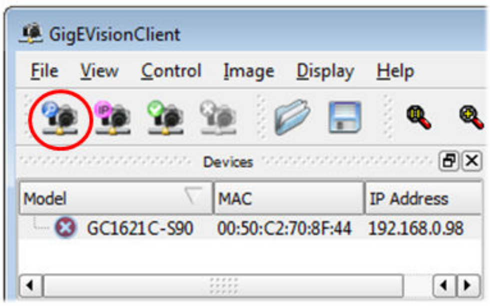


Figure 61: Find Devices icon

Note If none of the connected cameras was found, check the status of the network adapters and their configuration, as well as the status LEDs on the Ethernet connector of the camera, described in chapter *2.3.1 - Ethernet Interface*. Make sure everything is plugged properly and that the firewall settings are not blocking the connection to camera or GigEVisionClient.

After discovering one or multiple cameras, there is one of three available flags in front of each camera name displayed in the *Devices list*:

- Device available and waiting for connection
- Connection to device established
- Warning

In case the *Warning* sign is shown in front of a camera name, there could be two reasons:

1. The IP-address and subnet mask of network interface card or camera are invalid
2. The link speed of the used network interface is providing less than 1000 Mbit/s

For a quick start it is recommended to only use Gigabit Ethernet NICs, configured according to Table 64 shown in chapter *5.2 - LAN IP Configuration*.

In all cases it must be ensured that further NIC's within the PC are not configured for an IP-address within the same logical network as the NIC for the camera connection.

3.5.2.2 Device IP Setup

To change the IP address of a camera, select the target device in the list of devices and press the *Set Ip to Device* icon shown in Figure 62.

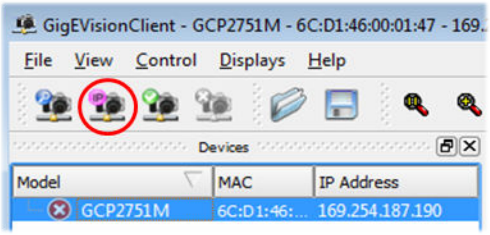


Figure 62: Set Ip To Device icon

A new window will open showing an access mask to the IP address, subnet mask and gateway configuration of the chosen camera. Make sure that the target IP address is not applied to another device in the network.

Figure 63: Set Ip To Device dialog

After fixing a valid IP address configuration to the camera, the warning symbol next to the camera model name will change like shown in Figure 64, the *Connect Device* icon can now be used to connect to the selected camera.

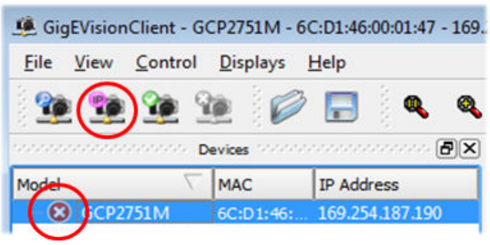


Figure 64: Connect Device icon

3.5.2.3 Device Properties

The *Device Properties* dialog contains all information and settings of the chosen camera, provided by the camera's GenICam file.

General informations about the camera selected from the list of discovered devices are displayed in the tab *Device Info*. Among others it contains the device name, firmware and hardware versions as well as the current IP configuration. It is accessible already before a connection has been established.

The *Parameters* tab shown in Figure 65 shows the parameters of the camera and is only accessible while a connection to the camera is established. It displays a tree of features extracted from the GenICam description file of the camera and enables the adjustment of camera settings according to the needs of the application.

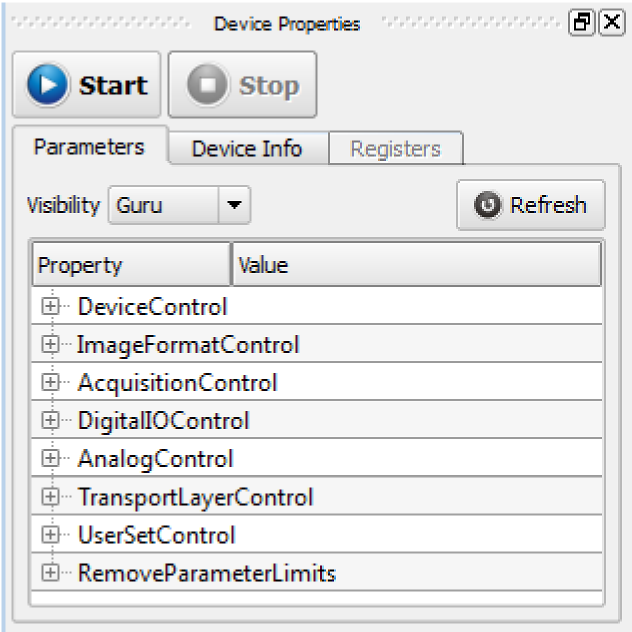


Figure 65: Device Properties - Parameters tab

According to the current settings of the camera, the acquisition can be started by pressing the *Start* button shown in Figure 66. To receive a continuous image stream from the camera, without having any external trigger signals applied, it must be ensured that the *AcquisitionMode* is set to *Continuous* and the *TriggerMode* is set to *Off*.

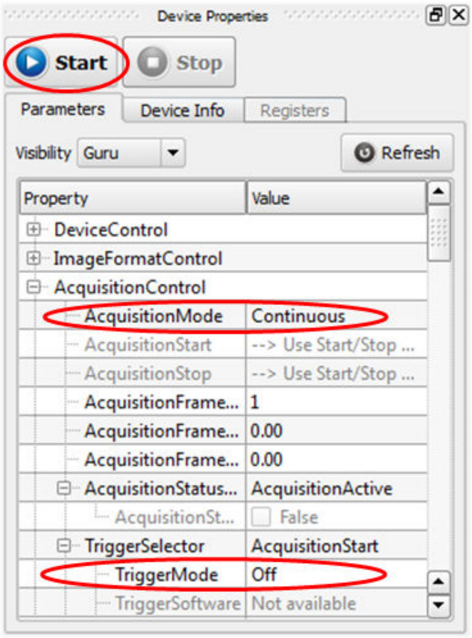


Figure 66: Device Properties - Starting a continuous stream

A running acquisition can be quit by pressing the *Stop*-button. Multiple acquisitions can be started in parallel by choosing further cameras, the output of the currently selected device is shown in the *Image Display* window.

3.5.2.4 Multiple Devices, Multiple Views

The GigEVisionClient supports the operation of multiple devices that are detected and connected to the network in parallel. The video stream of each device can be displayed in separated floating windows or grouped together in a *Preview* dialog. Figure 67 demonstrates these possibilities with two connected cameras. On the right the "Preview" dialog contains the video streams of the two cameras. This dialog can be enabled through *Control* ⇒ *Preview* in the menu bar. The floating displays are accessible through the menu *Displays* in the menu bar.

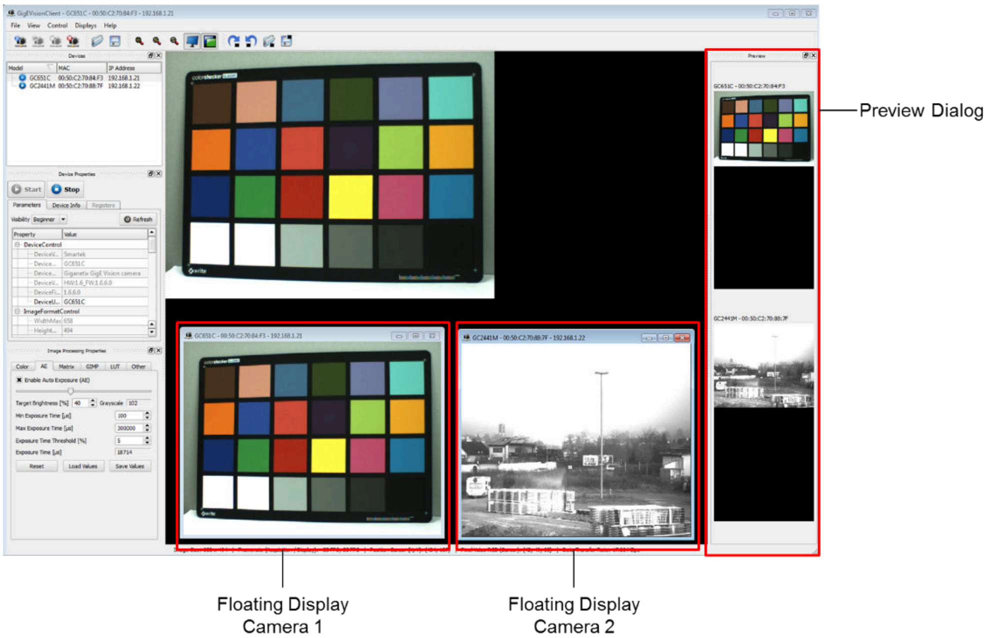


Figure 67: Preview Dialog and Floating Displays for multiple cameras

Note The maximum number of devices depends on the memory and performance of the host PC, as each of the devices will cause an amount of load to the system.

3.5.2.5 Image Processing

Image processing algorithms provided by the ImageProc API can be accessed within the *Image Processing* dialog, shown in Figure 68. It enables the user to apply and parameterize the available image preprocessing functions.

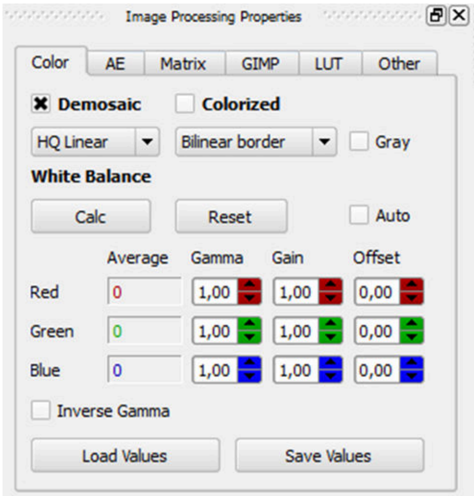


Figure 68: Image processing properties - Color tab

Table 38 shows an overview of the tabs and functions each tab includes. A deep description of all listed image functions can be found in chapter 6 - Image Processing in *GigEVisionSDK*.

Tab	Functions	Comment
Color	Demosaicing, white balancing, gamma, gain and offset correction	
AE	Auto Exposure	
Matrix	3x3 Matrix multiplication including value storing/loading	Only available for color cameras
GIMP	GIMP based color manipulation via hue, lightness and saturation	Only available for color cameras
LUT	Look Up Table generation, application and storing/loading	
Other	Image sharpening	

Table 38: GigEVisionClient - Image processing functions

3.5.3 API Settings Dialog

The *API Settings* dialog, accessible after activating it in the *Control* menu of the *Menu Bar*, displays various settings of the API, driver and memory management. The *API* tab, shown in Figure 69, allows the modification of all available API parameters and gives access to the packet resend settings and statistics of the current driver session, as well as it enables the user to rise or decrease the image buffer within the camera driver. This buffer represents space in the non-paged memory pool of Windows and can be used to improve the performance when loosing images because of low system performance.

Note Since the amount of memory in the non-paged memory pool is limited (Windows XP limits it to 256MB, Windows 7 limits it at 75% of physical RAM), the number of images in the image buffer must be calculated correctly.

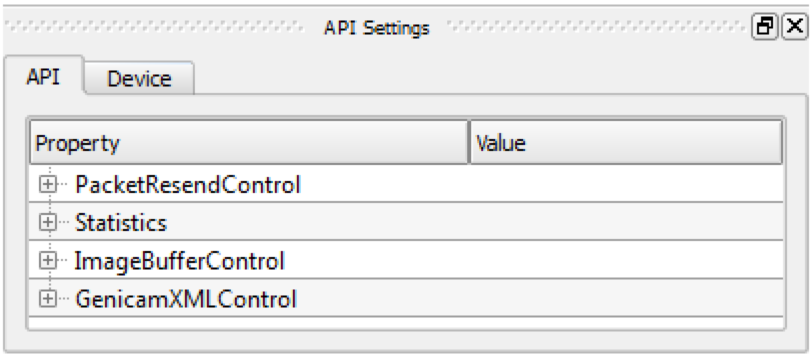


Figure 69: API Settings

Additionally the *Device* tab of the *API Settings* dialog provides access to the packet statistics on device side.

3.5.4 Log Dialog

The Log dialog contains logging information from SDK and cameras, shown in Figure 70.

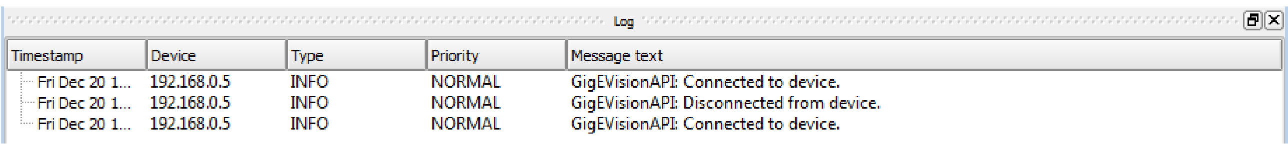


Figure 70: Log dialog with API logging

3.5.5 Firmware Update

The *GigEVisionClient* contains a module to update the firmware of a Giganetix camera. To update the firmware of a SMARTEK Vision camera, choose and connect the target camera in the GigEVisionClient and start the *Firmware Update* dialog via the *Control* category in the menu bar.

In the Firmware Update Dialog, shown in Figure 71, follow the following steps:

1. **Browse for Firmware Updates**
   Find and open a firmware to be uploaded to the camera by pressing the *Browse* button. The latest firmware can be requested from your local sales representative or at support@SMARTEKvision.com.

2. **Compatibility Check Passed**
   After selecting and opening a firmware file, the application will run a compatibility test between the device and firmware. If the selected firmware is compatible to the selected camera, the shown text is tagged as *"PASSED"* and the *Upload new firmware* to device button will become available.

3. **Flash Firmware**
   To upload and flash the firmware to the target camera, press the *Upload new firmware to device* button.

4. **Successful Update**
   In the last step of the firmware update the camera is restarted by the application. If this step was executed successfully, the update window can be closed and the camera is ready to be operated with the new firmware.

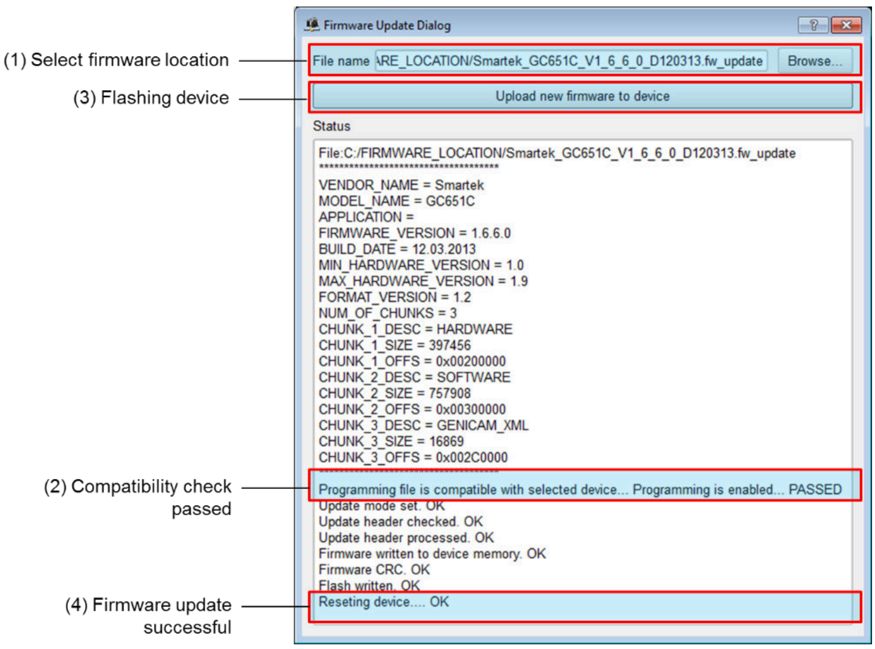


Figure 71: Firmware update dialog after the update is successfully executed

Note In case of any major errors during the update process, please repeat the firmware upload. Do not restart a camera before the process was finished successfully!

4 Image Acquisition

The following chapter gives a brief overview about the general principles of digital image acquisition based on the Giganetix series, starting at the point where the image was projected to the image sensor plane. It further includes a description of the camera's main functionality as well as the main configuration options of the image acquisition.

4.1 General Camera Architecture

The Giganetix camera series consist of multiple electronic components to convert incoming light to a digital signal, process it and send it to the host device or network. Figure 72 shows the simplified architecture of each camera, containing the image data path (orange) from the sensor to the Ethernet Network, as well as multiple control paths (red).

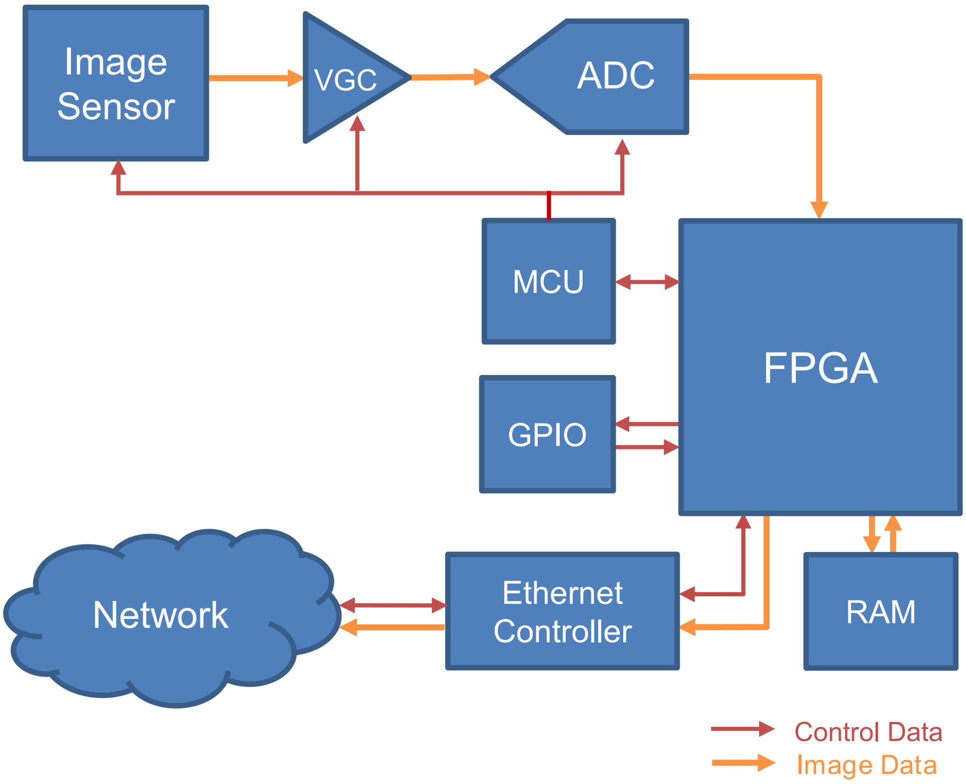


Figure 72: Camera Architecture Scheme

Like shown in Figure 72, the image data chain (orange) starts with the *Image Sensor* converting incoming light to electrical load. On usual area image sensors, over a million pixels are arranged in a two dimensional array on which the light of a scene is projected through a lens. Each pixel captures the photons of the light at a different point of the scene, making it possible to detect the whole scene within a defined grid. Hitting the sensor's active pixel array, photons generate electrons which in turn create an electrical load in each pixel, defining the intensity of each. The amount of electrical load depends on the strength of the light and the time frame for which the pixels are exposed to light, the so called *Exposure* or *Integration Time*.

Before the load of each pixel can be digitized, it needs to be amplified by a *Variable Gain Control* (VGC) circuit according to the input characteristics of the *Analog-to-Digital Converter* (ADC). The amplification factor of this component can be controlled via the *Analog Gain* through the camera control interface.

By default the signal is amplified as strong as just needed to completely drive the *ADC* when the pixels reach their full well capacity. Higher gain values will result in a cut off signal at high signal levels, lower gain values will not amplify the signal enough to ever reach a saturated digital image, even if the sensor reached its saturation. To improve the signal quality and remove a possible dark noise from the image, which is e.g. created by thermal influence, a so called *BlackLevel* value is globally subtracted from each pixel as well.

After the preparation, the signal of each pixel is digitized by the analog-to-digital converter. The bit depth of each digital pixel value is defined by the resolution of the ADC used, typically in range from 8 to 16 bits. All further image processing is done based on the digital signals and takes place in the camera's *FPGA*. The external memory (*RAM*) connected to the FPGA is used to buffer the image data, decoupling the data processing domain from the data transmission domain (Ethernet).

In the last step of the image processing chain, the final image data is passed to the *Ethernet Controller*. Here the data is segmented into GigE Vision compliant Ethernet packets which are sent over the Ethernet physical interface to the network or capture devices.

4.1.1 CCD Sensor Readout

The Giganetix camera family is equipped with a selection of CCD sensors from Sony and Truesense Imaging. Figure 73 broaches the Interline Transfer technology used in all of the equipped CCD sensors, as well as the individual camera front-end.

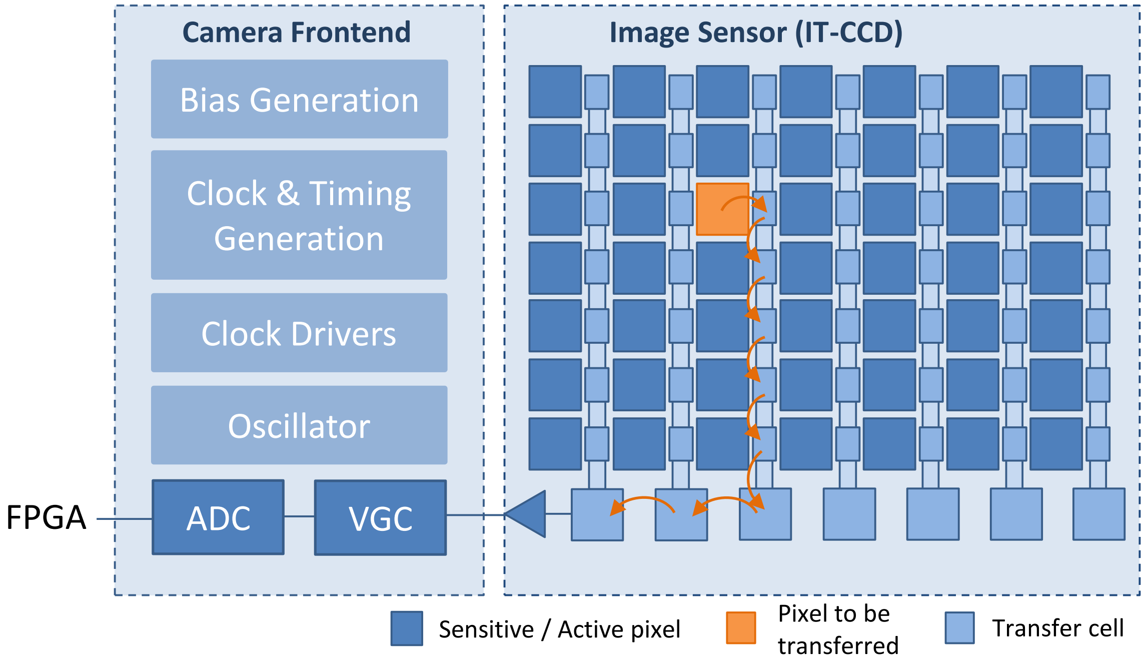


Figure 73: Giganetix Frontend with Single Tap Interline Transfer CCD

After the period of exposure, all collected charges are transferred at the same time from the active pixels into vertical shift registers, located beside each column of active- or photosensitive cells. As the transfer cells are not photosensitive, no mechanical shutter is needed. As all pixels are read out at the same time, Interline Transfer CCD sensors have a Global Shutter as well.

The charges from top of the vertical shift registers are moved line by line down to the horizontal shift register, shown in the bottom of the active array. From the horizontal shift register, charges are converted to voltages and moved out of the image sensor (from right to left). On the camera frontend, containing the sensor, the image signal is amplified (*VGC*) and digitized (*ADC*) and provided to the FPGA for further processing.

4.1.2 Multi-Tap CCD Sensor Readout

In contrary to classic Single Tap CCD sensors, the pixel array of Multi Tap CCDs is read out from several sides. The big advantage of this approach of parallel readout is the multiplied amount of pixel data which can be read at the same time. Depending on the count of taps, multi-tap sensors can easily reach a multiple of frame rates compared to single tap sensors.

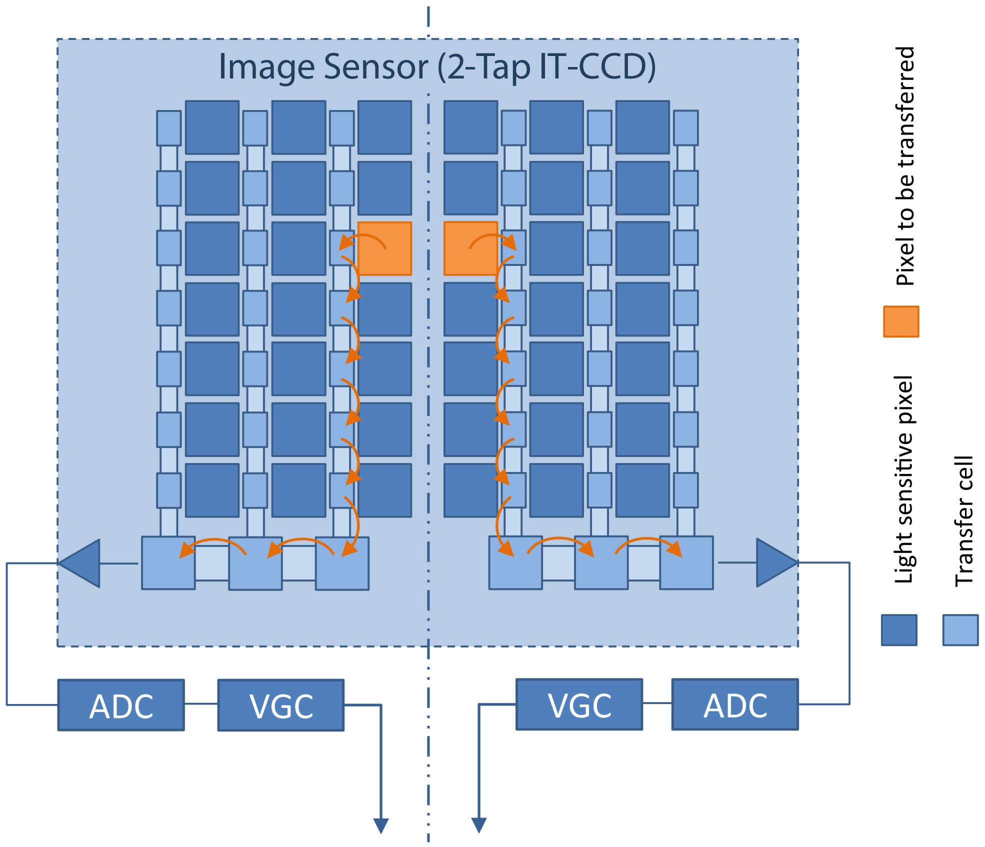


Figure 74: Dual Tap Interline Transfer CCD

Like shown in Figure 74, where the schematic of a dual tap or 2-tap sensor is shown, the active pixels are read out in the same way like on a Single Tap CCD, but from two sides. This mechanism leads to a doubled frame rate compared to an equally clocked single tap CCD, but also to an issue.

As both arrays are read out synchronously, the pixel data of each tap has to be amplified and digitized by an individual circuit. As electrical components are subjected to tolerances, each circuit behaves slightly different over temperature. This causes in slightly dissimilar brightness levels between the taps, shown in Figure 75 (left), which need to be matched for a proper functioning of the camera depending on the actual device temperature (right).

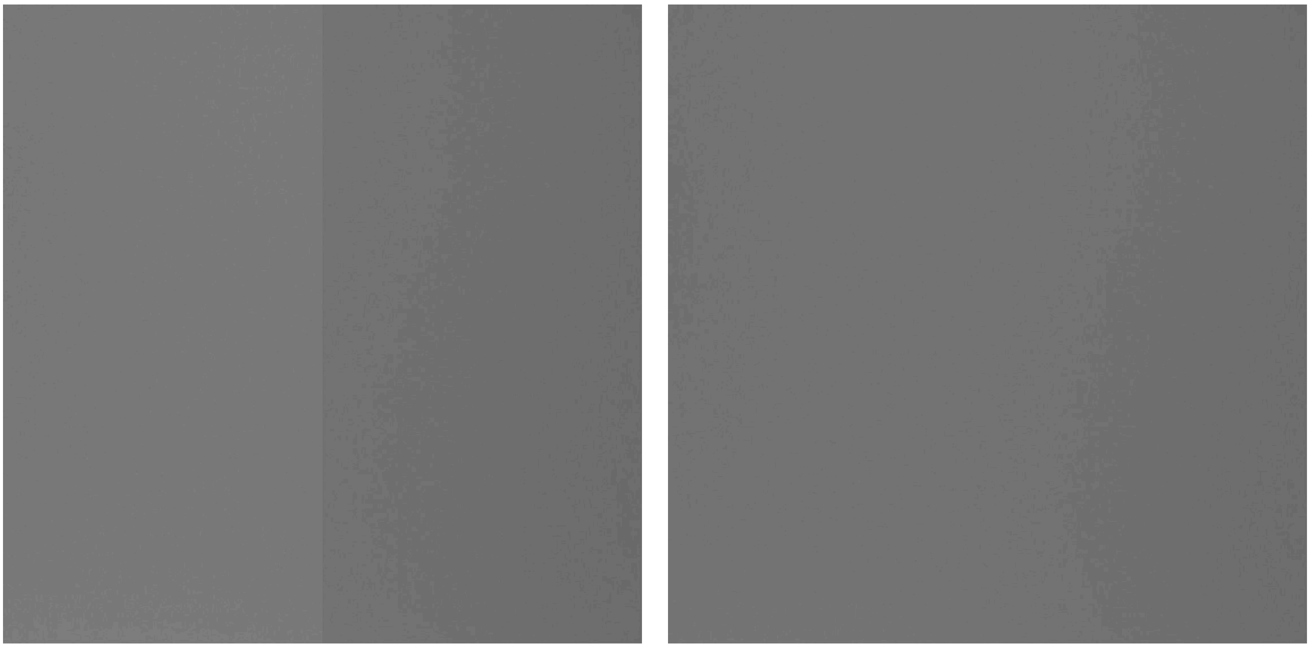


Figure 75: 2-Tap Sensor - Unbalanced image (left) and matched image (right)

Note

The cameras of the Giganetix family contain two mechanisms to appropriately match the sensor taps; cameras of the Giganetix series (Standard, GC-S90 and GC-BL) provide by default an automatic online matching which is described with its configuration parameters in chapter *4.3.3 - Automatic Tap Balancing*. All cameras of the Giganetix Plus series (GCP) are factory calibrated in their specified temperature range, configuration by the user is not necessary.

4.1.3 CMOS Sensor Readout

A CMOS sensor reads the accumulated charge of each cell in the image individually, where it was already converted to a voltage. There are several transistors at each pixel which do the conversion and make each pixel be addressable by the horizontal and vertical circuit, using more traditional wires. Because of the high demand for space by additional transistors on each pixel, the light sensitivity of a CMOS chip tends to be lower, as the photosensitive area shrinks with the amount of transistors.

Each pixel is read out and reset separately after each other. On Global Shutter CMOS sensors the charge of each pixel is additionally buffered in a non-photosensitive area of the pixel before, while on Rolling Shutter sensors the charge is read out directly from the exposed pixel. This postpones the moment of readout and thus shifts (Electronic Rolling Shutter) or extends (Global Reset Release) the duration of exposure from pixel to pixel (and line to line). Both architectures have their advantages and disadvantages; while a Rolling Shutter has problems in motion scenes due to the fact that the lower lines of the images are later exposed than the top ones, Global Shutter sensors show up additional noise and lower sensitivity due to their higher amount of transistors per pixel. In case of a Rolling Shutter the mentioned effect can be removed by using strong synchronized strobe illuminations or a mechanical shutter.

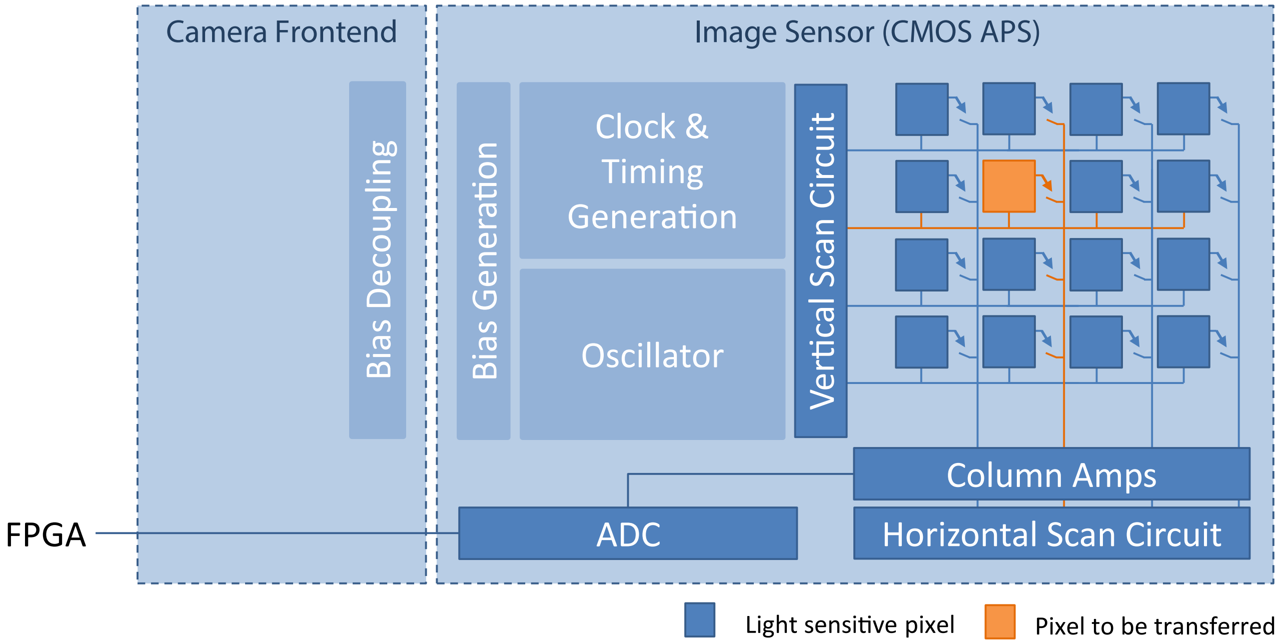


Figure 76: Giganetix Frontend with CMOS Active Pixel Sensor with integrated Gain and ADC

As shown in Figure 76, on CMOS image sensors the image data is already amplified in the sensor's *Column Amps* and digitized by the *ADC* before leaving the image sensor. Depending on the sensor type, also additional processing can already take place within the sensor. The output of the CMOS image sensors used is a digital signal which can directly be forwarded to the camera's FPGA. The electronics in the camera's frontend are mainly dedicated to provide clean and separated supply powers for the sensor and its periphery, and route the sensor control bus (I^2C).

4.1.4 CCD vs. CMOS - Sensor Performance

Both CCD and CMOS technologies use the same principle, they transform light into electric charge and convert it into electronic signals.

In a CMOS sensor, each pixel has its own charge-to-voltage conversion, and the sensor often also includes amplifiers, noise correction, and digitization circuits, so that chip outputs are digital bits. In a CCD sensor, each pixel's charge is transferred through a very limited number of output nodes to be converted to voltage, buffered, and sent off chip as an analog signal.

This difference in readout techniques has major impact on sensor limitations and capabilities. Eight properties describe sensor performance:

1. **Speed** - an attribute that favors CMOS over CCDs because most of the camera functions can be placed on the image sensor.
2. **Quantum Efficiency** - the ratio between output signal and unit of input light energy. Rolling Shutter CMOS sensors caught up massively within the past years and offer a similar performance.
3. **Uniformity** - is the consistency of response for different pixels under identical illumination conditions. CMOS were traditionally much worse than CCDs, however new amplifiers have made the illuminated uniformity of some CMOS close to that of CCDs.
4. **Dynamic range** - the ratio of a pixel's saturation level to its signal threshold. CCDs have the advantage here.
5. **Windowing** - CMOS technology has the ability to read out a portion of the image sensor allowing elevated frame rates for small regions of interest. CCDs generally have limited abilities in windowing.
6. **Shuttering** - the ability to start and stop exposure arbitrary, is superior in CCD devices. CMOS devices require extra transistors in each pixel to provide uniform (Global) shuttering and achieve similar results like CCD sensors.
7. **Biasing and clocking** - CMOS image sensors have a clear advantage in biasing and clocking, as they work on single bias voltage and clock level.
8. **Anti-blooming** - is the ability to easily reduce localized overexposure without ruining the rest of the image in the sensor. CMOS for the most part is immune to typical blooming. CCDs need higher engineering skills and additional hardware to remove blooming.

4.1.5 Color Imaging with Bayer Pattern

In an area image sensor pixels are arranged in a two dimensional array (see Figure 77). Each pixel contains a light sensitive photo diode that converts the incoming light intensity into an electrical voltage. The amount of light falling into a photo diode over a period of time, defined by the exposure or integration time, determines the pixel voltage level. Based on the technology of a photo diode, each pixel is sensitive for a wide range of wavelengths, covering on silicon based sensors the whole visible as well as near infrared wavelengths. All incoming photons are accumulated to one intensity, a separation of the different wavelengths and thus color information is therefore afterwards not possible.

To build up color images, an image sensor needs the ability to extract the color information already from the incoming light. One common way for this purpose is to place a color filter array (CFA) on top of the photosensitive cells, to catch significant wavelengths individually by filtering off all others and use them to recalculate full color information for each pixel. The Bayer color filter array is the most widely used filter array on image sensors, which uses the complementary colors red, green and blue. The main advantage of this filter array is that only one image sensor is needed to separate color information of the light at one time. In a Bayer filter array there are twice as many green as there are red or blue pixels, the reason behind this is the higher sensitivity of the human eye for the color green.

Note: All color cameras of the Giganetix family are equipped with area image sensors with Bayer pattern.

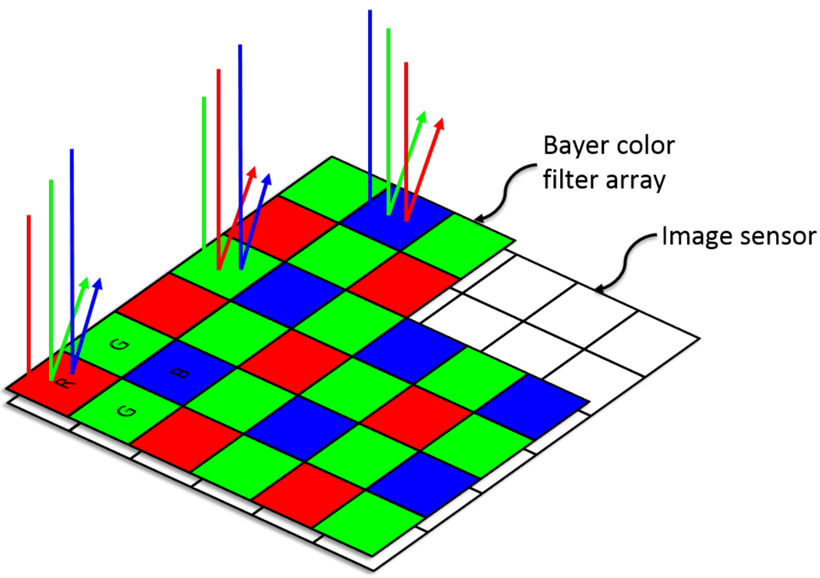


Figure 77: Bayer Color Filter Array placed on top of an area image sensor

Figure 77 illustrates a Bayer color filter array placed on top of an area image sensor:

- At a red color filter position, red light is fully transmitted, green and blue light are reflected or absorbed by the filter
- At a green color filter position, green light is fully transmitted, red and blue light are reflected or absorbed by the filter
- And at a blue color filter position, blue light is fully transmitted, red and green light are reflected or absorbed by the filter

In general the Bayer color filters are arranged in a 2-by-2 pattern where the green filter is used as twice as red or blue filter as described above. The first two pixels from top and left of the pixel array determine the name of the Bayer pattern. The Bayer pattern shown in Figure 77 is therefore called a "RG" pattern. This pattern is one of the four Bayer patterns available: GR, RG, BG and GB shown in Figure 78.

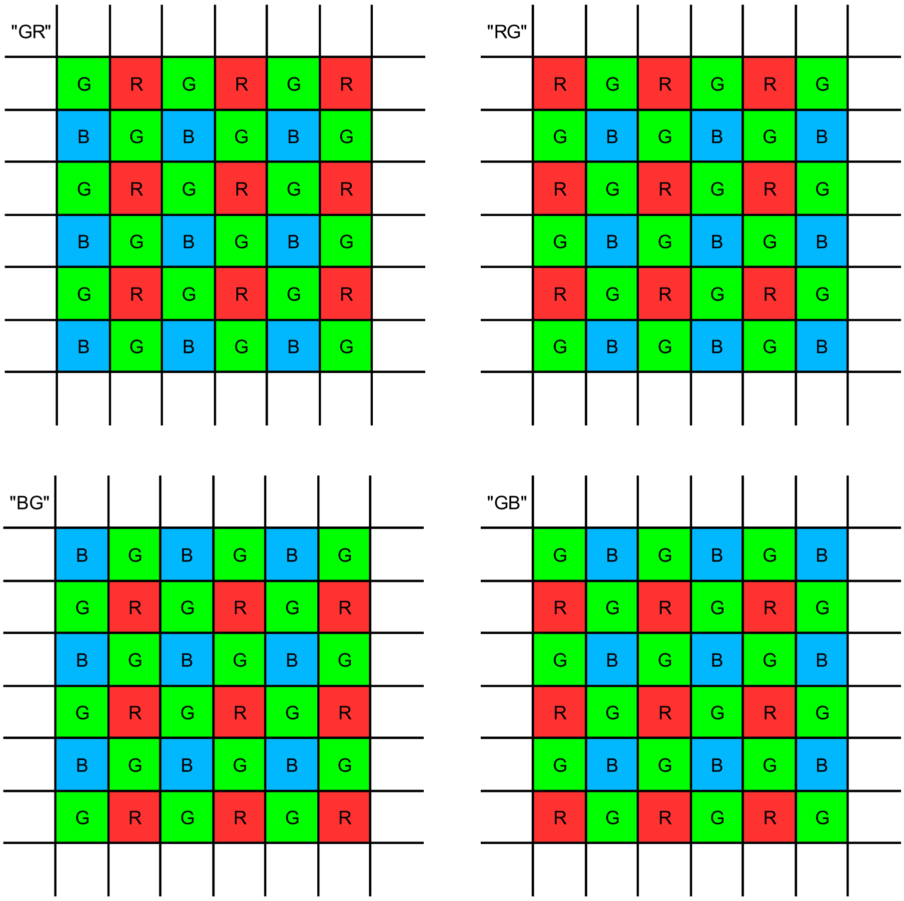


Figure 78: Bayer Color Filter Array placed on top of an area image sensor

Since each pixel accumulates only the intensity value of the red, green or blue light, there are missing information for displaying a color image. At the pixel position of a red color filter for example, the green and blue information are missing. To reproduce the full color information, various interpolation methods can be applied to calculate the missing values based on the neighbor pixels. Those interpolation methods are often called color filter array interpolation, demosaicing or debayering. For more detailed description of the debayering methods, please refer to chapter *6.2.6 - Color Filter Array Interpolation (Demosaicing / Debayering)* in this user manual.

4.2 Shutter types and Frame Readout

On digital image sensors with electronic shutters, three technologies of frame shuttering are common:

- Global Shutter
- Electronic Rolling Shutter (ERS)
- Electronic Rolling Shutter with Global Reset Release (GRR)

All three technologies show up very different characteristics, which are described in the following chapter.

4.2.1 Global Shutter Readout

On global shutter sensors, all lines of the image sensor are exposed at the same time for an equal amount of time to incoming light. The start of exposure is defined by an incoming frame start signal (e.g. a trigger), the duration of exposure is adjusted by the user, or applied by an external signal as well.

The procedure is shown in Figure 79; the pixel in all lines are reset and started being exposed at one time, after the incoming *Frame Start* signal is received. After the *Exposure Time*, the charges of all pixel are simultaneously transferred into protected pixels on the sensor, from where they are read out line by line. The active array can usually already be exposed again while the protected pixels are still read out.

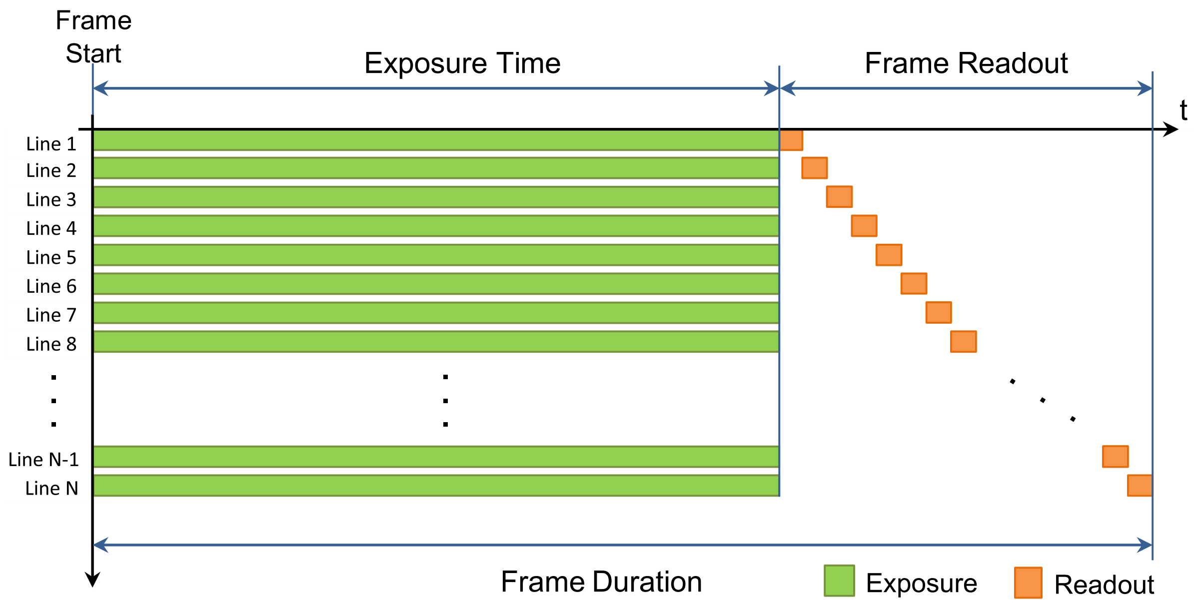


Figure 79: Global Shutter Frame Readout

Because of its characteristics to expose all lines over the same period of time, Global Shutter sensors are preferred especially for moving scenes where no additional mechanical shutter or strobe illumination is used.

To establish a global shuttering on CMOS sensor technology, further transistors need to be placed on each pixel to buffer the load of each while the sensor is read out. As this reduces the photo sensitive area of each pixel, the sensitivity of global shutter CMOS sensors tends to be smaller compared to electronic rolling shutter sensors. This is usually compensated by a micro lens above each pixel, which focuses the incoming light to the light sensitive surface.

4.2.2 Electronic Rolling Shutter (ERS) Readout

In contrast to the global shuttering, rolling shutter sensors start the exposure of each line not at the same moment. Each line is started to be exposed with an offset to the prior one, the exposure time of each line is defined by the user and effectively the same for all of them.

The process is shown in Figure 80; with the *Frame Start* signal, the exposure of line 1 is started. As Electronic Rolling Shutter sensors are not able to store the load of pixels in a non-photon-sensitive area, the exposure first ends with the individual pixel being read out. As the read out of all lines takes place in serial, the read out of each line is delayed by the prior ones; to keep the duration of exposure for all lines equal, the exposure start of each line is delayed about $t_{ReadRow}$ to the prior line as well. Beside some internal timing parameters and the read out frequency, $t_{ReadRow}$ is mainly affected by the image width. The total time for frame read out ($t_{FrameReadout}$) can be calculated by multiplying $t_{ReadRow}$ with the total count of lines in the frame.

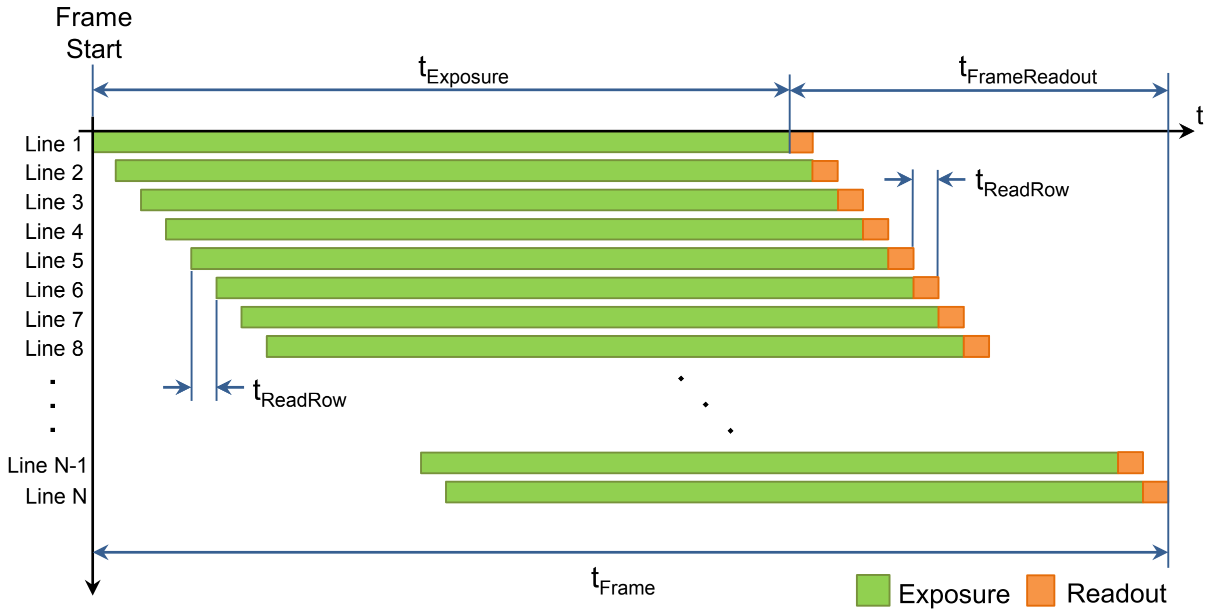


Figure 80: Electronic Rolling Shutter Frame Readout

The duration of readout per frame can be calculated with the following formula, by multiplying the time needed to read out each row with the total number of rows:

$$t_{FrameReadout} = t_{ReadRow} \times \mathrm{ImageHeight}$$

Table 39 shows the read-out time $t_{ReadRow}$ for the default image width of each CMOS model.

Model	$t_{ReadRow}$
GC1281	31.75µs
GC2041	53.31µs
GC2591	36.38µs
GC3851	23.09µs

Table 39: Read out time ($t_{ReadRow}$) per line for CMOS Sensors (ERS)

Due to the fact that the exposure duration of each line is shifted, each of them catches a different moment of the scene, what leads to unwanted effects especially in moving scenes. This effects can be reduced or completely removed in many cases by creating a controlled illumination situation.

Eliminating Rolling Shutter Effects

In many cases a strobe illumination or mechanical shutter can help to remove the rolling shutter effect in moving scenes by putting light onto the sensor only while all lines are within integration. Figure 81 shows this illumination window as $t_{Illumination}$, staring at $t_{IlluminationDelay}$.

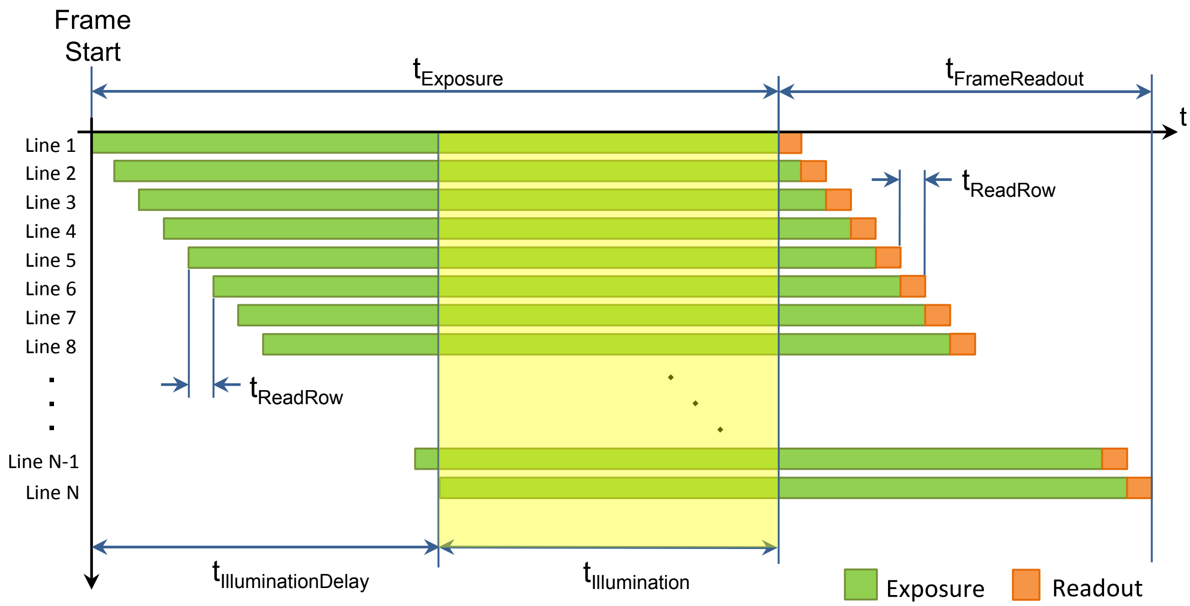


Figure 81: Electronic Rolling Shutter Frame Readout

Beyond the illumination period $t_{\text{Illumination}}$, ideally no light falls onto the sensor, to fully remove the rolling shutter effect. The timing of illumination or mechanical shutter can be calculated with the formulas below.

Delay of illumination / shutter open:

$$t_{\text{IlluminationDelay}} = t_{\text{ReadRow}} \times (\text{ImageHeight} - 1)$$

On time of illumination / shutter open:

$$t_{\text{Illumination}} = t_{\text{Exposure}} - (t_{\text{ReadRow}} \times (\text{ImageHeight} - 1))$$

4.2.3 Global Reset Release (GRR) Readout

The Global Reset Release is a variation of the Electronic Rolling Shutter and supported by particular CMOS sensors. Like the name already indicates, all lines are reset globally at the same moment and thus also started to be exposed at the same time. As shown in Figure 82, the start of exposure of subsequent lines is not delayed like on standard rolling shutters, the readout procedure stays the same. Since the exposure duration of each line is extended about t_{ReadRow} this way to its prior, the image lightens up line by line from top to bottom.

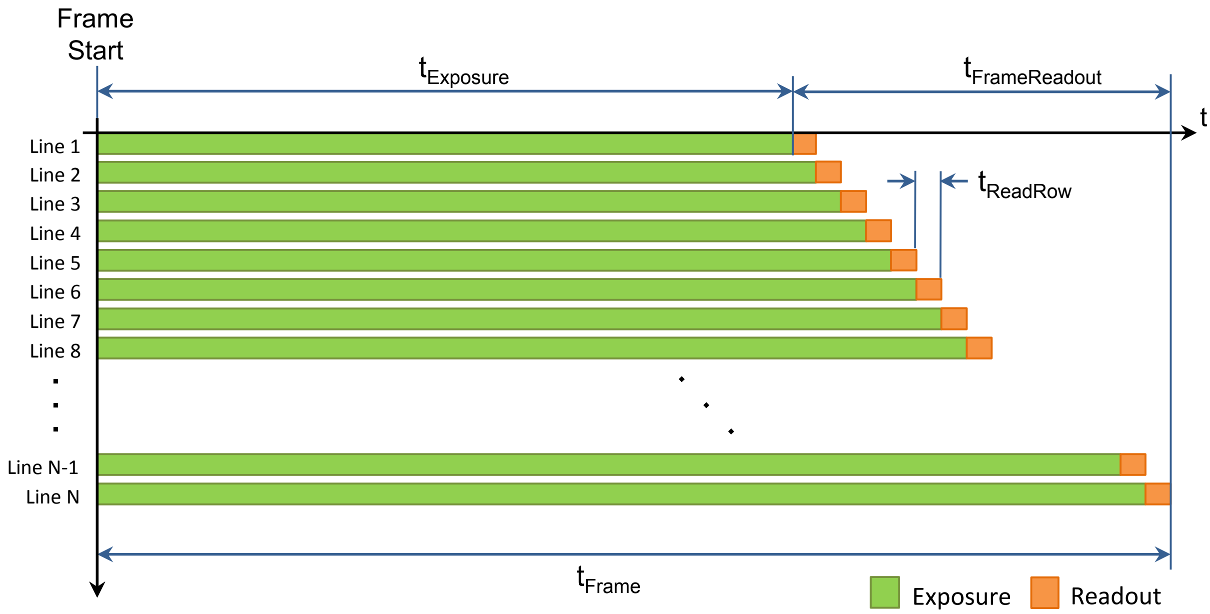


Figure 82: Global Reset Release (GRR) Frame Readout

Similar to the Electronic Rolling Shutter, the progression of brightness in the image can be reduced or even removed by a controlled illumination situation. The illumination of the sensor can in this case already be started with the sensor exposure, but must end with the exposure of Line 1, what corresponds to the overall exposure time configured in the camera.

4.3 Brightness and Sensor Signal Control

4.3.1 Exposure / Integration Time

The brightness of an image is influenced by the amount of light that falls on the image sensor, concerning both intensity and duration. The duration of time in which the photosensitive cells of the image sensor are exposed to the incoming light is called the exposure time or the integration time. While the intensity of light depends on the light source and the lens aperture, the exposure time can be controlled by modifying parameters of the camera.

Figure 83 demonstrates two settings of camera's exposure time. The left picture is captured with an exposure time of 10000 µs. For the right picture the exposure time is set to 22000 µs. The brightness difference of the two images is clearly visible. Due to the nearly linear behavior of the used sensors, doubling the exposure time results in an approximately doubled pixel intensity.

Figure 83: Different exposure time settings

The exposure time for SMARTEK Vision digital cameras is configurable by the GenICam *Float* property ExposureTime and expressed in microseconds (µs). Each camera has a predefined range of values, depending on the sensor and its technology. The minimum and maximum exposure time for each camera model is shown in *2.2 - Sensor Information and Technical Specification (All Models Separate)* and can be determined programmatically via the *IDeviceInterface* of the *gige* API.

Function	Description
bool GetFloatNodeValue ("ExposureTime", double &nodeValue) const	Get value of IFloat node ExposureTime.
bool SetFloatNodeValue ("ExposureTime", double nodeValue)	Set value of IFloat node ExposureTime.
bool GetFloatNodeMin ("ExposureTime", double &nodeMinValue) const	Get minimum value of IFloat node ExposureTime.
bool GetFloatNodeMax ("ExposureTime", double &nodeMaxValue) const	Get maximum value of IFloat node ExposureTime.

Table 40: ExposureTime - Access through API

Table 40 shows important C++ API functions in context of the exposure time, a full description of the interface and further supported languages can be found in the API documentation located in the GigEVisionSDK installation folder.

Note The duration of the exposure time can affect also the maximum frame rate per second (FPS) of the camera. The exposure time in µs for each frame must not exceed $\frac{10^6}{\text{TargetFPS}}$ to be able to reach the target frame rate *TargetFPS*.

The automatic modification of the camera's exposure time within user applications can be realized by using the ImageProcAPI provided by the GigEVisionSDK. For detailed description of the automatic exposure feature please refer to chapter *6.2.3 - Auto Exposure and Auto Gain*.

4.3.2 Analog Gain and Black Level

After the charge was read out from the active pixel array it needs to be amplified according to the input levels of the analog-to-digital converter, or even higher to lighten up dark scenes without raising the exposure time or adding light.

Analog Gain

Figure 84 illustrates a typical image acquisition signal chain in SMARTEK Vision digital cameras. The analog voltage generated by the sensor will be passed through the Variable Gain Control where it is amplified by a factor, configurable by the camera's Gain value.

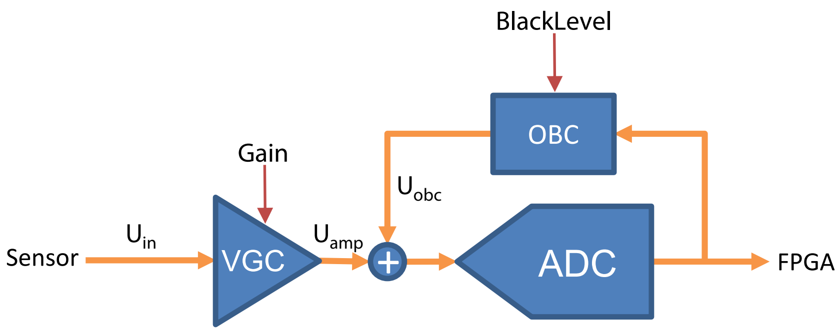


Figure 84: Typical signal chain in a CCD/CMOS image sensor

In SMARTEK Vision digital cameras gain values are expressed in decibels (dB), the analog gain defines the ratio between the output and input voltage value in a base 10 logarithmic scale:

$$\mathrm{Gain}_{\mathrm{dB}} = 20 \times \log_{10} \frac{\mathrm{U}_{\mathrm{amp}}}{\mathrm{U}_{\mathrm{in}}}$$

For calculating the linear amplification factor from the gain value in dB, the reverse function can be applied:

$$\frac{\mathrm{U}_{\mathrm{amp}}}{\mathrm{U}_{\mathrm{in}}} = 10^{\frac{\mathrm{Gain}_{\mathrm{dB}}}{20}}$$

The Giganetix cameras provide the real value of the analog-to-digital converter to the user. As the sensor signal at saturation is usually a fraction of the level needed to generate a maximum digital value at the analog-to-digital converter, it is per default higher than 0 dB (or factor 1 in linear scale). Usual default values are between 12 dB and 15 dB, where the useful signal is fitted only to the input of the analog-to-digital converter, but not enhanced to improve e.g. the image brightness.

Gain modification is also useful for enhancing the image brightness, especially in low light condition. Increasing a gain value means increasing the intensity of each pixel, resulting in a brighter image. However, the image noise will also increase when gains are increasing. Figure 85 shows two images with different gain settings. The image on the right is captured with a gain value of 14 dB, while the image on the left is captured with a gain value of 19 dB. Like expected the left image appears brighter than the right one.

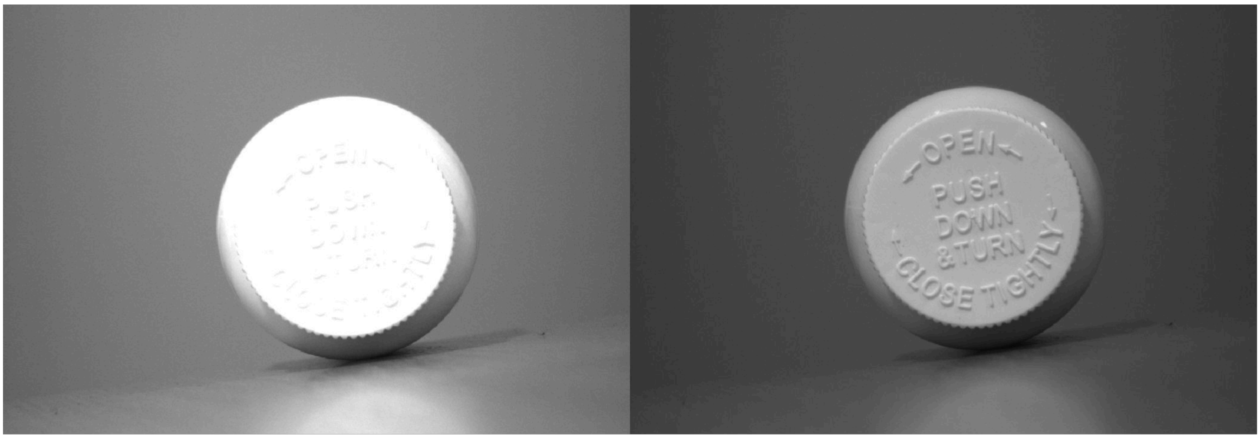


Figure 85: Captures under different gain settings

The analog gain on SMARTEK Vision digital cameras is configurable by the GenICam *Float* property *Gain* in combination with the *Enumeration* property *GainSelector*. The minimum and maximum gain values for each camera model is shown in 2.2 - Sensor Information and Technical Specification (All Models Separate) and can be determined programmatically via the *IDeviceInterface* of the *gige* API.

The following tables show important C++ API functions in context of the gain. As several cameras provide multiple gain registers giving access to the gain of individual color channels or various taps, the type of gain needs to be chosen first by the *GainSelector* property, shown in Table 41.

Function	**Description**
bool GetEnumNodeValue ("GainSelector", double &nodeValue) const	Get value of Enumeration node GainSelector.
bool SetEnumNodeValue ("GainSelector", double nodeValue)	Set value of Enumeration node GainSelector.
bool GetEnumNodeValuesList ("GainSelector", StringList &nodeValuesList) const	Get list of values for Enumeration node GainSelector.

Table 41: GainSelector - Access through API

The values for the Enumeration data type *GainSelector* can be found in Table 42, their availability depends on the camera architecture and can be requested from the camera as shown in Table 41.

GainSelector Values	**Description**
All, Tap1, Tap2, Tap3, Tap4	Global Gain (All color channels), individual per tap (multi tap sensors)
Red, Green, Blue	Individual Gain (per Color Channel)

Table 42: GainSelector - Values

After the appropriate gain has been selected via the *GainSelector*, its value can be get/set from the *Gain* property. Table 43 shows the most important C++ functions.

Function	Description
bool GetFloatNodeValue("Gain", double &nodeValue) const	Get value of IFloat node Gain.
bool SetFloatNodeValue("Gain", double nodeValue)	Set value of IFloat node Gain.
bool GetFloatNodeMin("Gain", double &nodeMinValue) const	Get minimum value of IFloat node Gain.
bool GetFloatNodeMax("Gain", double &nodeMaxValue) const	Get maximum value of IFloat node Gain.

Table 43: Gain - Access through API

Black Level

As shown in Figure 84 as well, the analog-to-digital conversion circuit includes beside the ADC an additional component with the target to remove dark current noise from the signal of each pixel. Dark current is a charge of each pixel which is generated continuously by thermal energy within the silicon lattice, even when no light enters the sensor. As its charge in the photosensitive pixels is not connected to the amount of light entering, it is no useful signal and needs to be removed before digitizing the signal, as it negatively effects the signal to noise ratio.

To help to remove the dark current noise, image sensors usually provide an array of optically shielded pixels (lines and columns, covered by a non-transmissive metal coating). Due to the coating they are at no time exposed to light and are taken as reference value for the dark current. The Optical Black Clamping (OBC) circuit, shown in Figure 84, ascertains the average digital value of the dark pixels and subtracts it from an offset, named as *clamp level*. The overall value (usually negative) is then added to the amplified signal:

$$U_{obc} = U_{amp} + \left(\mathrm{ClampLevel} - \frac{\sum_{i=0}^{n}(U_{dark_i})}{n}\right)$$

The *clamp level* can be accessed by the *BlackLevel* property of the camera. It provides percentage access to the value range of the clamp level register of the analog frontend (CCD) or the sensor (CMOS) and is by default set to 0. It can be used to reduce the amount of Dark Noise subtracted from the signal or to add a user defined offset to the signal. The available clamp level ranges are shown in Table 44.

Camera Type	Clamp Level (in DN)	BlackLevel (in % of Clamp Level)
All Models (CCD Sensors)	0 to 1023	0 to 100
All Models (CMOS Sensors)	-255 to 256	0 to 100

Table 44: Range Overview of Clamp Level for CCD and CMOS Cameras

Note

SMARTEK Vision digital cameras based on CCD technology can only apply *Analog Gain* and *BlackLevel* values to all channels (per tap) at one time. Individual gain settings (digital) can be achieved by software using the ImageProcAPI in the GigEVisionSDK.

4.3.3 Automatic Tap Balancing

Various models of the Giganetix series are equipped with dual tap CCD sensors. Like described in 4.1.2 - Multi-Tap CCD Sensor Readout, it is necessary to match the signal levels of all taps to receive a uniform overall image. Cameras of the Giganetix series (GC, GC-S90, GC-BL) therefore provide an *Automatic Tap Balancing* mechanism, which by default continuously adjusts the gain and black level of each tap.

The *Automatic Tap Balance* algorithm calculates the mean value of every n-th pixel residing along both sides of each tap border. Figure 86 shows this exemplarily on the basis of a 2-tap image, where relevant pixels at a *TbpVerticalStep* of 5 are tagged in green.

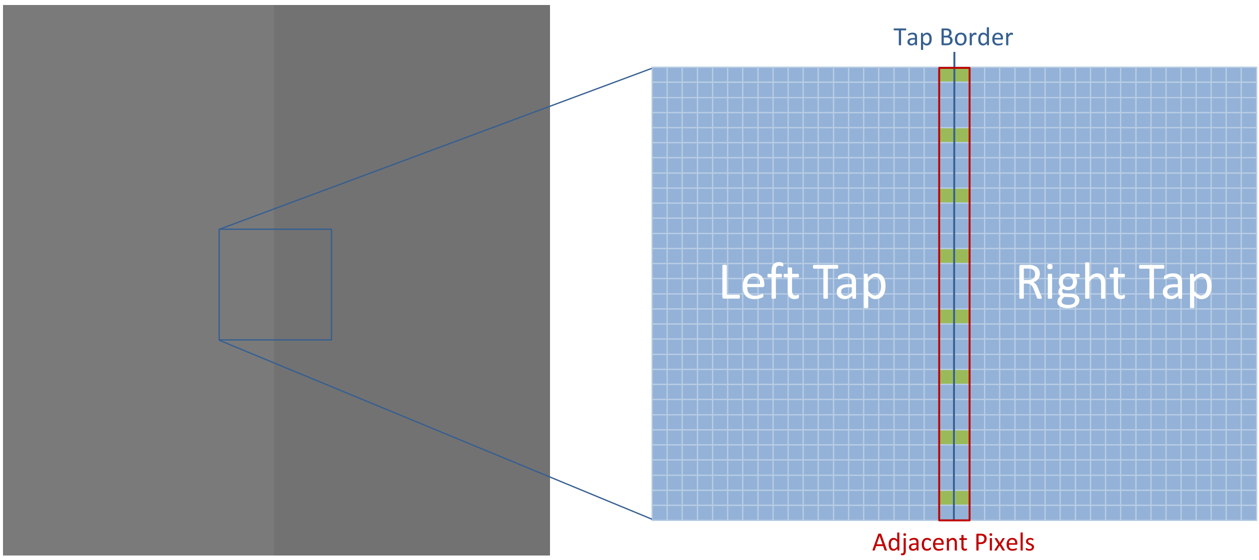


Figure 86: 2-Tap Sensor - Unbalanced Image (left) and Schematic of Adjacent Pixels

The algorithm takes into account only pixels where the difference between adjacent pixels on different taps is less than *TbpPixelDiffTreshold*. The resulting values on both taps are averaged over a count of frames defined in *TbpFramesToAvg* and compared; if the difference between the taps is larger than *TbpTapDiffTreshold* or *TbpTapDiffTresholdPercent*, the gain will be adjusted based on the size of the difference. In this process, also the difference in black level on both taps is calculated and corrected if bigger than *TbpTapDiffTresholdBL*.

An overview of the parameters is shown in Table 45 and can be accessed via the camera properties by the *GigEVisionClient* or directly via the *API*.

Parameter	Type	Description
TbpVerticalStep	Integer	Vertical step used in Tap Balance algorithm
TbpFramesToAvg	Integer	Number of frames averaged and used in Tap Balance algorithm
TbpPixelDiffTreshold	Float	Maximum difference between adjacent pixels on different taps to include them in calculation
TbpTapDiffTreshold	Float	Maximum allowed difference between taps
TbpTapDiffTresholdPercent	Float	Maximum allowed difference between taps in percent
TbpTapDiffTresholdBLoAvg	Float	Maximum allowed black level difference between taps.

Table 45: Auto Tap Balancing - Parameters

Note

By lowering the *TbpVerticalStep* parameter, the algorithm uses more pixels in calculation and consequently provides more precise results. On the other hand, using more pixels in calculation causes the algorithm to be slower and can lead to a decreased frame rate.

Note

Increasing the *TbpFramesToAvg* parameter increases the amount of frames used in averaging, localized single frame tap differences thus have smaller impact on the final result when tap difference is compared to the threshold. On the other hand, increasing the number of frames used for averaging increases the delay or reaction time between detecting the difference between taps and adjusting it.

The operation of the automatic tab balancing algorithm can be controlled via the property *GainAutoBalance*, adjusting the gain, and *BlackLevelAutoBalance*, adjusting the Black Level of the camera. Both have three operation modes, listed it Table 46.

Value	Description
Off	Tap balancing is disabled; taps can be balanced manually via the gain and black level properties after choosing the target tap
Once	Balancing of taps is done once until both taps are matched, the algorithm is then set to *Off*
Continuous	Tap balancing algorithm is running continuously (default)

Table 46: Parameters for GainAutoBalance and BlackLevelAutoBalance

4.3.4 Digital Shift

The *DigitalShift* property is part of the camera's analog controls and allows a data selection from the full bit depth of the sensor (14 Bit) to 8 Bit. As shown in Figure 87, all cameras by default use the 8 Most Significant Bits (MSB) of the 14 Bit Analog-to-Digital Converter (ADC) to create 8 Bit pixels, the Least Significant Bits (LSB) are cut off.

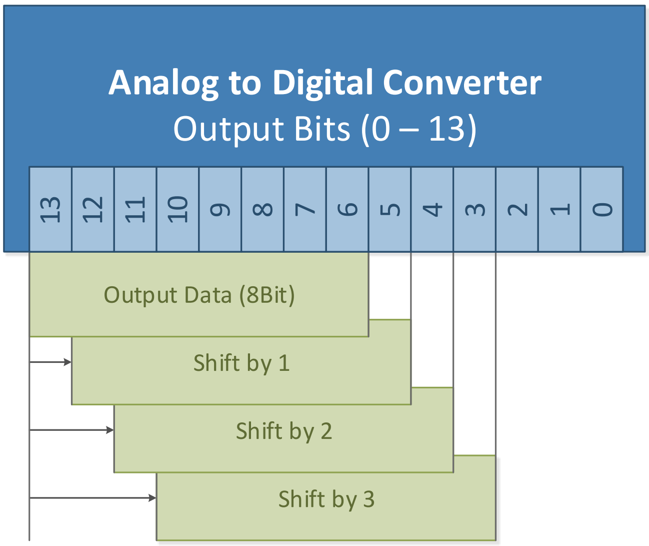


Figure 87: Digital Bit Shifting at Analog to Digital Converter

The *DigitalShift* property of the camera allows to shift the selected bits into the direction of the LSBs. As e.g. by default bits 6 to 13 are used, a DigitalShift value of 1 outputs bits 5 to 12 from the ADC. Table 47 shows the ADC bits outputted at each DigitalShift value.

DigitalShift Value	Bits at ADC
0 (default)	6 to 13
1	5 to 12
2	4 to 11
3	3 to 10
4	2 to 9
5	1 to 8
6	0 to 7

Table 47: DigitalShift values and used ADC bits

Shifting the significant pixels to lowers has two main effects; similar to doubling the analog amplification of the signal, the brightness in the image will double with each step. It thus enhances the maximum signal raise possible by the analog gain. Further it makes the lower bits of the ADC accessible to detect very low signals while transferring 8 bit pixels, without a further amplification of the signal.

4.4 Area of Interest Control (AOI)

Usually the complete pixel array of the sensor is transmitted and displayed. As some applications and situations do not need the full resolution of the sensor, it is on nearly all models of the Giganetix series possible to read out just a so called *Region* or *Area of Interest* (ROI / AOI). It defines a sub-part within the pixel array of the sensor which is transmitted only, and makes it thus possible to reduce the amount of image data, focusing on the significant information.

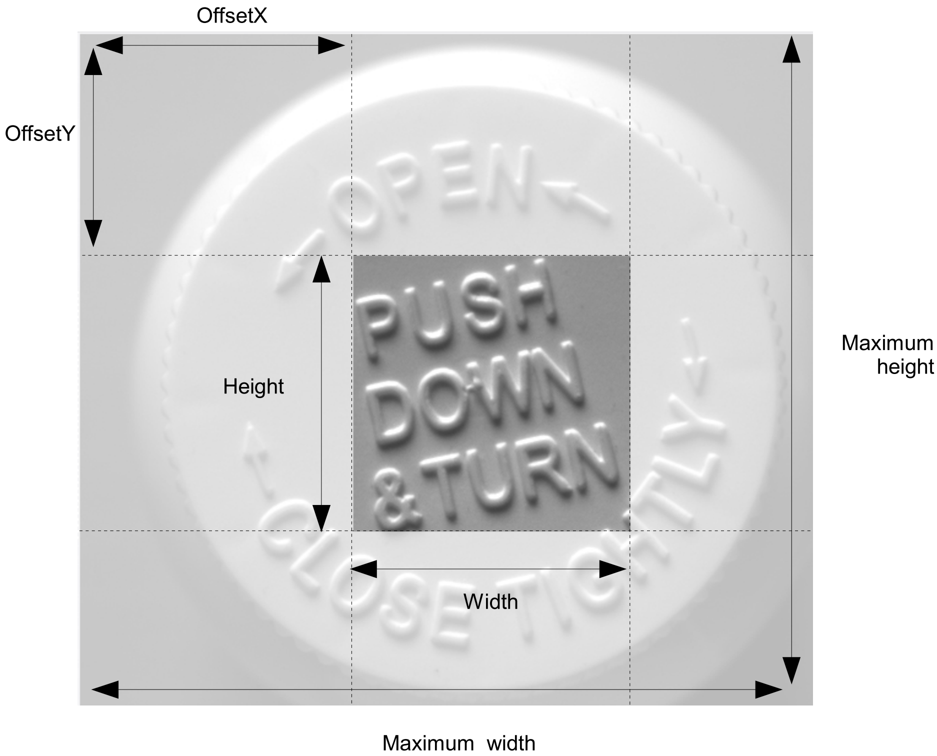


Figure 88: Area of Interest

The parameterization of the *Area of Interest* takes place in four parameters, shown in Figure 88 and Table 48. They clearly define the sub-window within the image respectively to the sensor array.

Value	Type	Description
Width	Integer	Horizontal size (in pixel) of the sensor / image section
Height	Integer	Vertical size (in pixel) of the sensor / image section
OffsetX	Integer	Horizontal offset (in pixel) of the sensor / image section
OffsetY	Integer	Vertical offset (in pixel) of the sensor / image section

Table 48: Parameters to define an Area of Interest

While the camera is capturing images, changes only to the parameters that determine the position of the AOI are allowed (*OffsetX, OffsetY*). The parameters which define the size (*Height, Width*) are inaccessible.

4.5 Acquisition Control

The following section is about controlling the image acquisition of SMARTEK Vision digital cameras. It contains a detailed description about the different acquisition modes, how to control external triggering and how the image acquisition rate can be limited. Table 49 gives a brief overview about all features that are available to control the image acquisition in the cameras.

Image Acquisition Features	Short description
AcquisitionMode	Defines the number of frames to be captured. Three options are available: • Continuous • SingleFrame • MultiFrame
AcquisitionStart	Start acquisition
AcquisitionStop	Stop acquisition
AcquisitionAbort	Abort acquisition
AcquisitionFrameCount	Number of frames to acquire in MultiFrame acquisition mode
AcquisitionBurstFrameCount	Number of frames to acquire for each FrameBurstStart trigger
AcquisitionFrameRate	Controls the acquisition rate (in Hz) at which the frames are captured
Trigger Features	**Short description**
TriggerMode	Enable/Disable the trigger mode. Two options are available: • On • Off
TriggerSoftware	Generate a software trigger
TriggerSource	Select the source that fires a trigger signal: • Line1: Physical Input Line 1 • Line2: Physical Input Line 2 • Software
TriggerActivation	Define the clock edge of the input signal for activate triggering • Rising Edge • Falling Edge
TriggerDelay	Specify the delay in microseconds (µs) to incoming trigger signals.

Table 49: Camera features for image acquisition control

In the following chapter the image acquisition is divided into two general types - the *Free Run* operation, where the camera streams images as fast as possible and the *Triggered* operation, where the camera waits for a further signal by an external source to start the acquisition of a count of images.

4.5.1 Free Run Operation

In Free Run mode the camera starts the acquisition of images as soon as the *AcquisitionStart* command was received by the device. Images are streamed with a by parameters fixed frequency, which by default corresponds to the maximum of the camera. By the Acquisition Modes it is furthermore possible to define how many images are acquired and streamed after receiving the *AcquisitionStart* command, until the acquisition is stopped again.

4.5.1.1 Acquisition Modes

The *AcquisitionMode* property controls the acquisition mode of the device. It defines the number of frames captured during the acquisition and the way the acquisition stops. It can take any of the values shown in Table 50.

Value	Description
Continuous	Frames are captured continuously until stopped by the AcquisitionStop command
SingleFrame	The camera captures only one frame and stops the acquisition
MultiFrame	The camera captures a specific number of frames set by the AcquisitionFrameCount property and stops the acquisition

Table 50: AcquisitionMode values

In order for the camera to run in free run, in which the camera acquires and transfers images at maximum configured frame rate, the *TriggerMode* properties for all *TriggerSelector* need to be set to *Off*.

4.5.1.2 Acquisition Frame Rate

The *AcquisitionFrameRate* property is a feature which limits the frequency at which images are captured by the camera. Using the *AcquisitionFrameRate* feature it is possible to decrease the number of frames the camera acquires and transmits in free run mode, which consequently lowers the Ethernet bandwidth needed by the camera.

This feature is useful in situations where the Ethernet bandwidth is limited, like in applications where several cameras acquire images using one single Gigabit Ethernet link.

Setting the *AcquisitionFrameRate* property to zero effectively disables the feature, allowing the camera to acquire and transfer images at maximum frame rate.

4.5.2 Triggered Operation

The trigger operation mode enables the user to precisely synchronize the camera with a further device or software application. The *AcquisitionStart* command sets the sensor in stand-by, waiting for a trigger signal. In contrary to the free run mode, the sensor is already initialized when a trigger initiates the integration, which is thus started with a minimum of latency.

Similar to the free run mode, also the trigger mode allows several kinds of operation. The selection of a trigger mode is done with the *TriggerSelector* property. Each trigger mode has its own parameters, all of them can be active at the same time. The camera is in trigger operation mode as soon as one of the modes selectable by the *TriggerSelector* is enabled via its *TriggerMode* property.

4.5.2.1 Trigger Selector

The *TriggerSelector* property provides access to the settings of the different trigger operating modes supported by the camera, shown in Table 51.

Value	Description
AcquisitionStart	Starts the acquisition like configured in AcquisitionMode
FrameStart	Starts the acquisition of a single frame
FrameBurstStart	Starts the acquisition of multiple frames; the count of frames is defined in the *AcquisitionBurstFrameCount* property.

Table 51: Supported Types of Triggers

All available modes can be configured separately and are valid in parallel, allowing to assign different behavior to each trigger source.

4.5.2.2 Trigger Mode

The property *TriggerMode* enables and disables the triggered operation of the camera. As soon as it is enabled for at least one *TriggerSelector* property, the camera's sensor falls in stand-by mode where it waits for an external signal defined in the *TriggerSource* property. The *TriggerMode* property is individually available for each *TriggerSelector* and can take one of the values shown in Table 52.

Value	Description
On	Enables trigger operation for the current TriggerSelector
Off	Disables trigger operation for the current TriggerSelector
FrameBurstStart	Starts the acquisition of multiple frames; the count of frames is defined in the *AcquisitionBurstFrameCount* property.

Table 52: Trigger Mode

While all *TriggerMode* properties are set to *Off* and the *AcquisitionMode* property to Continuous, the camera acquires continuously images.

4.5.2.3 Trigger Source

The *TriggerSource* property specifies the source which is used to initiate the trigger signal. An internal signal or one of the physical input lines can be selected as the trigger source. The selected *TriggerSelector* must have its *TriggerMode* set to On, *TriggerSource* can take any of the values shown in Table 53.

Value	Description
Line1	Uses the physical Input Line1 as trigger source
Line2	Uses the physical Input Line2 as trigger source
Software	Uses a Software Trigger as trigger source; the *TriggerSoftware* command can be send to the camera via the API

Table 53: Trigger Sources

4.5.2.4 Trigger Activation

For the external trigger signals applied on the physical input lines of the camera available in the *TriggerSource* property, it is possible to define the kind of edge which initiates a trigger. *The TriggerActivation* property offers two values described in Table 54.

Value	Description
RisingEdge	Trigger initiated with Rising Edge
FallingEdge	Trigger initiated with Falling Edge

Table 54: Trigger Activation modes

Figure 89 shows the exposure period of the sensor triggered by a rising edge, while Figure 90 shows the exposure period of the sensor triggered by a Falling Edge.

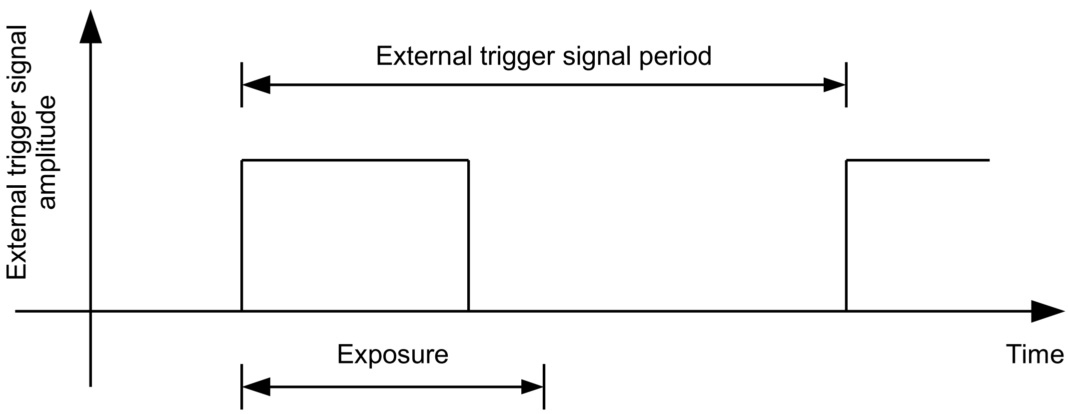


Figure 89: Exposure with a rising edge of the trigger

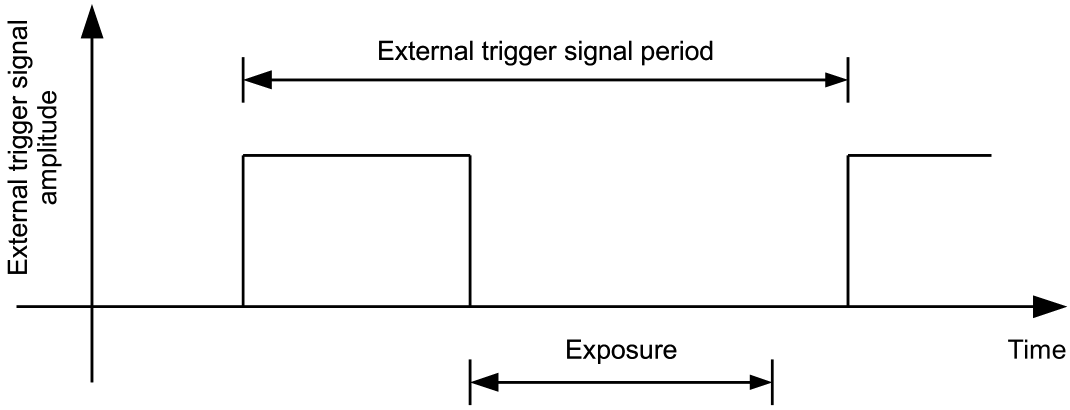


Figure 90: Exposure with a falling edge of the trigger

4.5.2.5 Trigger Delay

The *TriggerDelay* property defines a period of time for which an incoming trigger signal is delayed, until it is internally used to trigger the image sensor. The trigger delay is expressed in µs and can be set manually by software. For external signals, entering a physical input line, a general latency of 2µs is added by the input line circuitry of the camera. Together with the *TriggerDelay* it represents the signal latency in the camera until the image sensor is triggered.

A further description of the complete trigger process can be found in *4.6.1 - Input Lines*.

4.6 Digital Input / Output Control

The digital inputs and outputs of the Giganetix series can be used to synchronize the camera with other devices and cameras. The camera can be triggered on a rising or falling edge of the input trigger signal, or trigger other devices on configurable events. The physical interface is provided via the *General Purpose Input and Output* (GPIO) connector, described in 2.3.2 - Power and I/O-Interface.

Each physical line is configured separately and can be selected by the *LineSelector* property. The property *LineMode* contains if the currently selected line is an *Input* or *Output*. Table 55 describes all available configuration properties.

Property	Type	Description
LineSelector	Enumeration	Select the line for configuration; all further properties contain the values based on the selected line. Values are: • Line1 • Line2 • . . .
LineMode	Enumeration	Contains if the currently selected line is an Input or Output
LineStatus	Boolean	Current status of the selected line
LineSource	Enumeration	Source event driving the output line
LineFormat	Enumeration	Internal (electrical) circuit of the line
LineDebouncerTime	Float	Define the debouncer time of input lines (in μs)

Table 55: Trigger Sources

4.6.1 Input Lines

The camera's input lines can be used to trigger an acquisition of the camera on external events. The assignment of the physical input lines as a frame or acquisition trigger is described in Chapter *4.5.2 - Triggered Operation*. Figure 91 shows the partial process of a complete image acquisition. The incoming electrical signal of the external source is filtered by the *LineDebouncer* and raises the internal trigger signal (if valid). The internal circuit adds a fixed trigger latency stated in the camera's specification (usually $\sim 2\mu$s) to which the user defined *TriggerDelay* is added until the exposure is started.

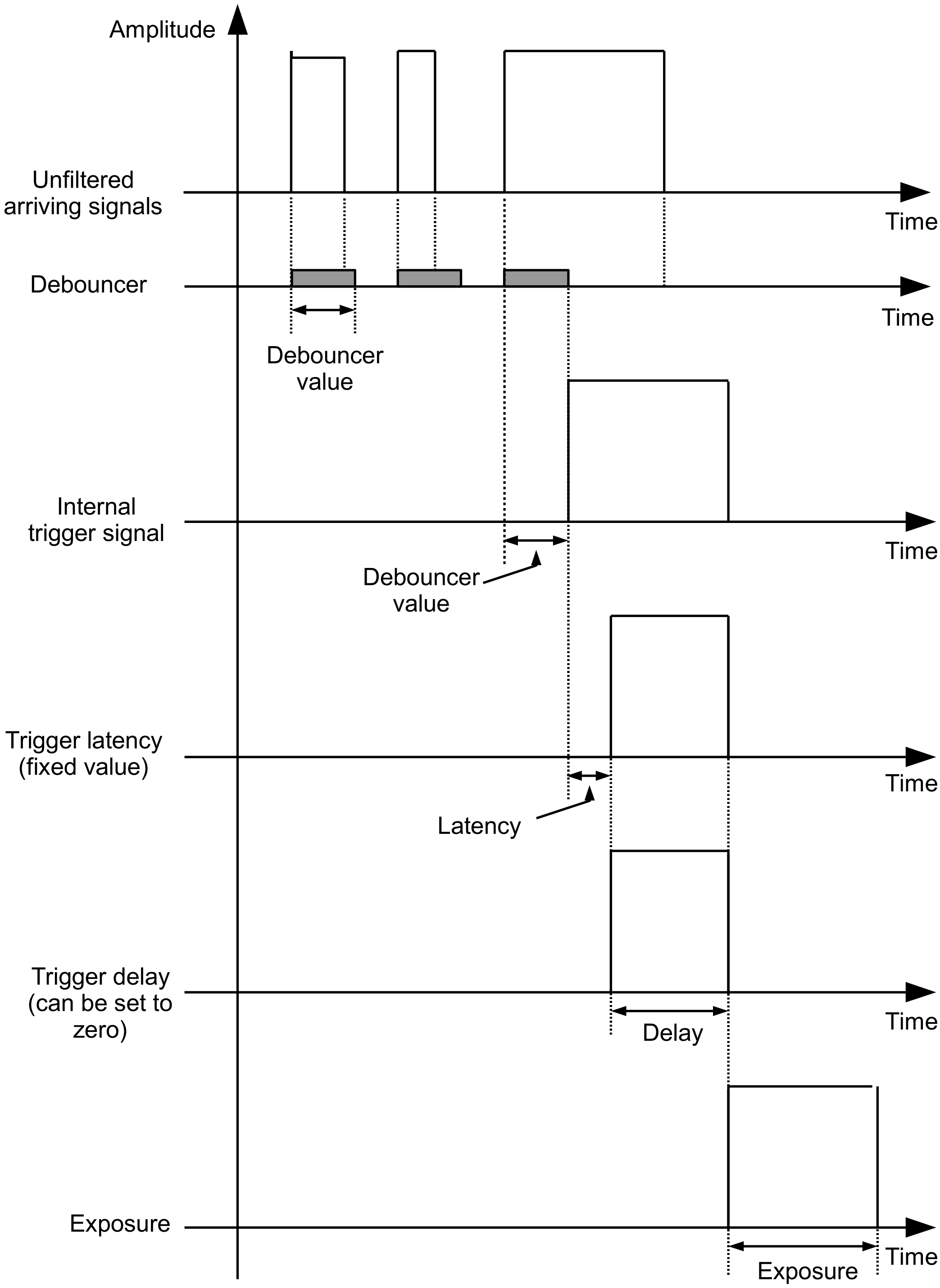


Figure 91: Partial process of image acquisition

Line Debouncer

The *LineDebouncer* property defines the minimum time interval that an input signal must remain active in order to be recognized as valid trigger. The line debouncer is used to prevent possible unwanted trigger events as it eliminates short noises that could easily be interpreted as trigger signal. The function of the trigger debouncer is shown in Figure 92; two glitches are ignored by the debouncer because the width of these signals is shorter than the debouncer time value. The third signal is accepted as a valid trigger signal as its width is longer than the debouncer time limit. The *LineDebouncerTime* feature is used to set the line debouncer time expressed in µs.

The line debouncer time effectively increases delay time between external trigger signal and internal trigger signal used to start the exposure, so it should be set large enough to filter unwanted glitches that could trigger the camera, but small enough to keep the delay as small as possible.

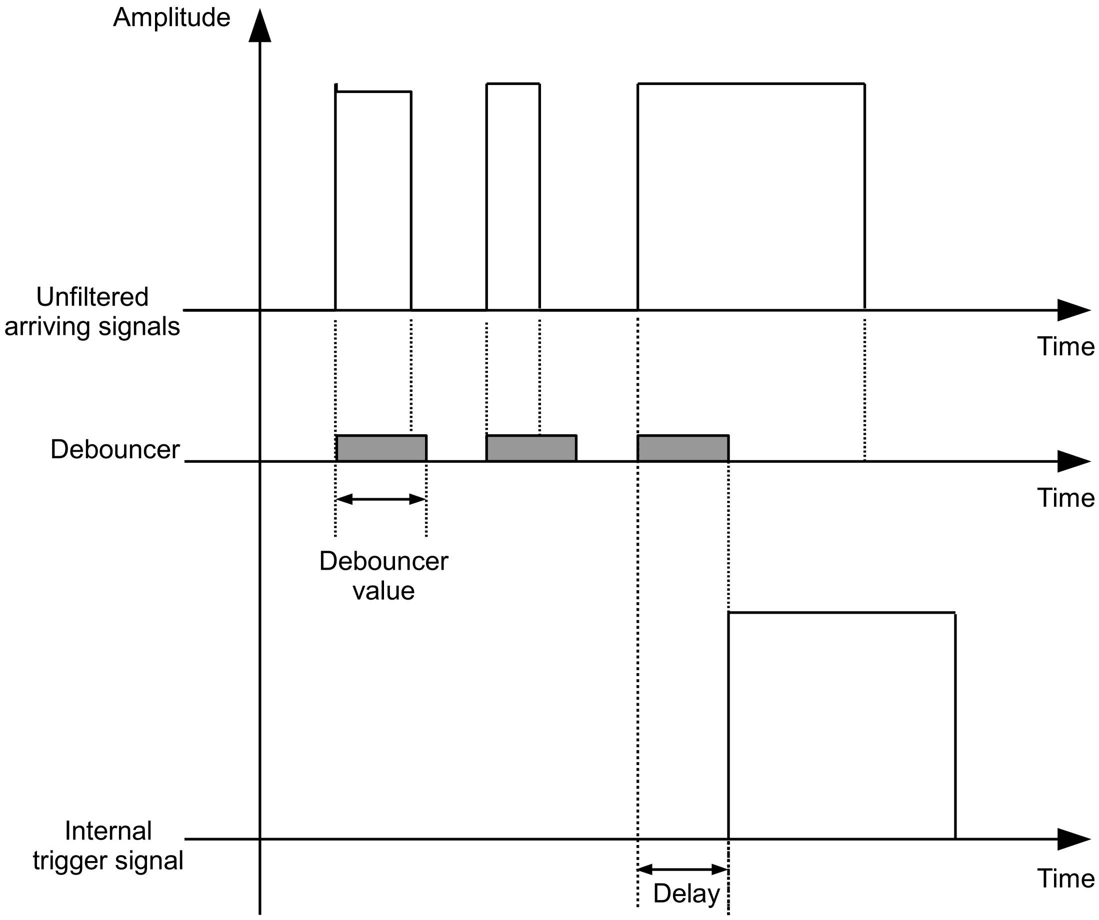


Figure 92: Line debouncer function

4.6.2 Output Lines

The physical output lines are usually used to synchronize the camera to external devices in situations where it makes sense that the camera is the master. Usual use cases are for example the synchronization of external illuminations to the sensor exposure or to drive mechanical actuators by the software application.

A full list of possible events assignable by the *LineSource* property to each output line is shown in Table 56.

Value	Description
UserOutput1 / UserOutput2	Set to High / Low by the software application with the UserOutputSelector / UserOutputValue properties
AcquisitionTriggerWait	High while the camera waits for a trigger for one or more frames
AcquisitionActive	High while camera acquires one or more frames
FrameTriggerWait	High while camera waits for frame trigger
FrameActive	High while camera captures a single frame

Table 56: Trigger Sources

While nearly all events available for the *LineSource* property are raised by the current acquisition state of the camera, the *UserOutput* can be defined by the user and thus be used to set a physical output line manually. The value of this property can be accessed after selecting the appropriate value by the *UserOutputSelector*, according to Table 57.

Value	Type	Description
UserOutputSelector	Enumeration	Select between UserOutput1 and UserOutput2
UserOutputValue	Boolean	Value of the selected UserOutput

Table 57: User Outputs

4.6.3 List of Supported Features

Series	Giganetix			Giganetix Plus
Interface	GigE Vision			GigE Vision
On-Camera Features	**GC**	**GC-S90**	**GC-BL**	**GCP**
Continuous Streaming (free run)	●	●	●	●
Triggered Operation (single / multi frame)	●	●	●	●
Exposure Control	●	●	●	●
Frame Rate Control	●	●	●	●
Partial Scan (ROI / AOI / WOI)	●[1]	●[1]	●[1]	○
Binning	●[2]	●[2]	●[2]	○
Reverse X (Horizontal Mirroring)	○	●	○	○
Reverse Y (Vertical Mirroring)	○	●	○	○
Analog Gain Control[3]	●	●	●	●
Analog Black Level Control[3]	●	●	●	●
Online Tap Balancing[4]	●	●	●	○
Factory Tap Calibration[4]	○	○	○	●
Digital Shift	○	○	○	●
Software Trigger	●	●	●	●
External Trigger (Line)	●	●	●	●
Line Debouncer (Trigger)	●	●	●	●
Line Input Delay (Trigger)	●	●	●	●
Acquisition / Exposure / Frame Active (Output)	●	●	●	●
Acquisition / Frame Trigger Wait (Output)	●	●	●	●
User Defined Outputs	●	●	●	●
Configuration Storing (User Sets)	●	●	●	●
IP Configuration (LLA / DHCP / Persistent)	●	●	●	●
Jumbo Frame Size (in Bytes)	4000	4000	4000	8000
Inter Packet Delay	●	●	●	●
Time Stamps	●	●	●	●

[1] Supported only in vertical direction by models with multi-tap CCD sensors
[2] Not supported by models with color CCD, multi-tap CCD and individual CMOS sensors
[3] Overall and tap independent, separate color channels only on CMOS models
[4] Multi-tap CCD sensors only

Table 58: Camera / API feature list (1/2)

Series	Giganetix			Giganetix Plus
Interface	GigE Vision			GigE Vision
Image Processing (Software)	**GC**	**GC-S90**	**GC-BL**	**GCP**
Automatic White Balance	●	●	●	●
Automatic Exposure Control	●	●	●	●
Lookup Table	●	●	●	●
Gamma Correction	●	●	●	●
Color Correction (3x3 Matrix)	●	●	●	●
Hue Saturation Lightness	●	●	●	●
Histogram	●	●	●	●
Sharpening	●	●	●	●
Pixel Data Formats				
Mono8	●	●	●	●
Mono16	●	●	●	●
Bayer8	●	●	●	●
Bayer16	●	●	●	●
Hardware				
Housing	●	●	○	●
Angled Sensor Head (90°)	○	●	●[5]	○
Inputs (opto coupled)	2	2	2	2
Outputs (opto coupled)	2	2	2	2
Power over Ethernet	○	○	●	●

[5] Flexible positioning, sensor head connected via FPC cable to mainboard only

Table 59: Camera / API feature list (2/2)

5 Image Transmission over Gigabit Ethernet

The network interface of SMARTEK Vision digital cameras is designed to be fully compatible with the GigE Vision standard. The following section describes features of the data interface of the Giganetix series as well as the SMARTEK Vision GigEVision Filter Driver. Further, several optimization settings of the network driver are introduced and the pixel structure of the image data is elaborated.

5.1 Smartek GigE Vision Filter Driver

Ethernet packets can come from various sources and do not have to be in order. This makes it necessary that each data segment is usually routed through the whole network stack of the operating system until it is delivered to the target application. The CPU load can especially at high data rates be significantly affected by this process as well as the latency of the image stream. The UDP protocol, used for the transmission with low latencies, is furthermore not able by default to handle packet loss - packet collisions lead inevitably to a loss of image data.

To optimize the data transmission and add features like an optimized packet resend mechanism, SMARTEK Vision provides its own GigE Vision filter driver. The filter driver separates streaming video packets from the rest of network data already before the network stack of the operating system gets access to them and forwards them directly to the application. It is designed to be compatible with the most network adapter cards and significantly lowers the CPU load needed to service the network traffic between the PC and the camera(s).

5.1.1 UDP Packet Resend Mechanism

The *Packet Resend* mechanism is a driver feature that, when enabled, tries to regain packets that have been lost during transmission. It checks the order of the incoming packets and detects if one or even a group of packets is missing in a stream. Depending on the parameters settings the driver will then send one or several resend requests to the camera which resends the appropriate packets. Table 60 shows the basic driver parameters available.

Parameter	Type	Description
SetParametersToDefault	CMD	Resets all parameters of the Packet Resend mechanism to the default values
MaxImageSize	Integer	Maximum image size that the Packet Resend mechanism will handle
EnablePacketResend	Boolean	Enables / Disables the Packet Resend mechanism
AcceptIncompleteImage	Boolean	Enables / Disables the acceptance of images where payload packets are missing
LineFormat	Enumeration	Internal (electrical) circuit of the line

Table 60: Packet Resend Parameters (1/2)

Table 61 lists further parameters, allowing a detailed configuration of the *Packet Resent* mechanism. All this parameters mainly affect the performance and the robustness of the packet resending, changes should only be done carefully.

Parameter	Type	Description
PacketResendTimeout	Integer	The elapsed time (in ms) before the first resend request for a missing packet is sent to the camera. The default value is 0 ms, meaning the request for a missing packet will be sent instantly. This parameter applies only once to each missing packet after the packet was detected as missing.
PacketResendResponseTimeout	Integer	Represents how long (ms) the Packet Resend Mechanism will wait for response after sending a resend request, until another resend request is sent.
MaxResendPacketRetry	Integer	Represents the maximum number of resend requests sent for a missing packet.
MaxMissingPacketWaiting	Integer	Maximum time (in ms) the missing packet is waited for. When this time expires, there will be no more resend requests sent to camera even if the driver did not send all resend request specified with MaxResendPacketRetry and the packet will be considered as lost.
MaxNextPacketWaiting	Integer	Maximum time (ms) that the resend mechanism will wait for the next packet. If this time expires and there are still retries left, the resend request is sent again.
MaxMissingPacketsCount	Integer	Maximum number of missing packets in one frame. If the frame has more missing packets then this value it will be dropped.
MaxNewImagesPending	Integer	Maximum amount of new images pending in the buffer. Current image is dropped if this amount is exceeded.
MaxNewPacketsPending	Integer	Maximum amount of incoming payload packets pending in the buffer. Current frame is dropped if this amount is exceeded.
MaxIncompletePackets	Integer	Maximum amount of missing payload packets from a block of the image to be accepted.

Table 61: Packet Resend Parameters (2/2)

Note: In healthy networks it is not necessary to recover more than a small number of packets per hundreds of transmitted images. Should the amount of packet resends rise to a unnatural height, check the correctness of the physical network setup (cabling, switches) and the network optimization settings located in chapter *5.3 - Network Interface Optimization*.

Example 1

Figure 93 illustrates the packet resend mechanism with the following assumptions:

- Packet *1007* is missing within the stream of packets and has not been recovered
- *MaxResendPacketRetry* parameter is set to 2

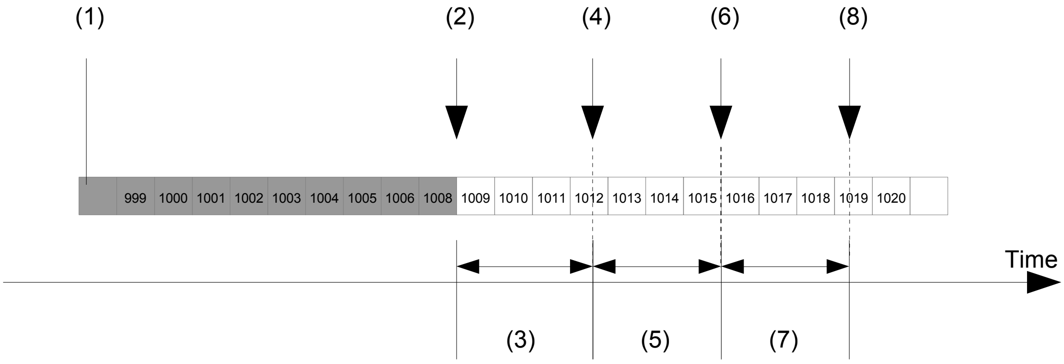


Figure 93: Packet Resend example when MaxResendPacketRetry value has exceeded

Corresponding to Figure 93, the workflow of the Packet Resent mechanism would look like described below:

1. Stream of packets. Gray indicates packets that have been checked by the driver, white packets have not yet been checked yet.
2. As packet *1008* is received, packet *1007* is detected as missing.
3. Interval defined by the *PacketResendTimeout* parameter.
4. The *PacketResendTimeout* is expired, the first resend request for packet *1007* is sent to the camera. The camera does not respond with a resend.
5. Interval defined by the *PacketResendResponseTimeout* parameter.
6. The *PacketResendResponseTimeout* expires and second resend request for packet *1007* is sent to the camera. The camera does not respond with a resend.
7. Interval defined by the *PacketResendResponseTimeout* parameter.
8. As the maximum number of resend requests has been sent (*MaxResendPacketRetry*) and the last *PacketResendResponseTimeout* has expired, packet 1007 is now considered as lost.

If a group of packets is missing (for example *1000, 1001, 1002 and 1003*), only one resend request will be sent covering all connected packets.

Example 2

Figure 94 illustrates the packet resend mechanism with the following assumptions:

- Packet *1007* is missing within the stream of packets and has not been recovered.
- *MaxResendPacketRetry* is set to 2.
- *MaxMissingPacketWaiting* is set to a value that expires before second resent request is sent.

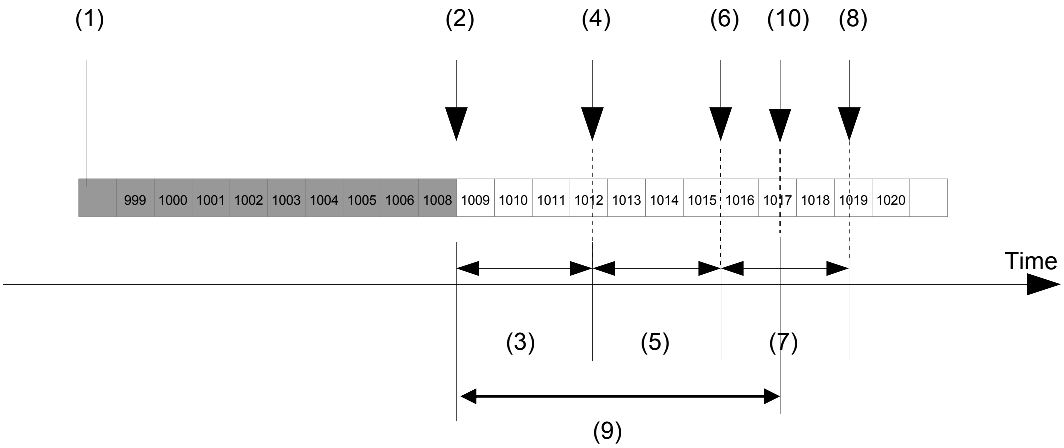


Figure 94: Packet Resend Mechanism example MaxMissingPacketWaiting value has exceeded

Additionally to the description in Example 2, the workflow of the Packet Resent mechanism would be enhanced by the following definitions:

1. Interval defined by *MaxMissingPacketWaiting* parameter.
2. As the *MaxMissingPacketWaiting* time has expired, missing packet is considered as lost.

5.1.1.1 API Statistics

The *Packet Resent* statistics in the *API* can be accessed by the parameters described in Table 62.

Parameter	Type	Description
ResetAll	CMD	Resets all current statistics
MissingPackets	Integer	Count of missing packets
PacketResendsAmount	Integer	Count of resend requests
LostPackets	Integer	Count of packets that were declared as lost
LostImages	Integer	Count of images that were declared as lost
IgnoredPackets	Integer	Count of packets that are ignored, usually packets that are already analyzed or packets that do not belong to this stream
IncompleteImages	Integer	Count of processed incomplete images
AllPackets	Integer	Count of all received packets
UnknownDevice	Integer	Count of all unknown devices
LeaderPackets	Integer	Count of all leader packets that are processed
PayloadPackets	Integer	Count of all payload packets that are processed
TrailerPackets	Integer	Count of all trailer packets that are processed
UnknownPackets	Integer	Count off all packets that have wrong packet format and were discarded

Table 62: Packet Resent statistic parameters

5.1.1.2 Device Packet Statistics

The Packet Resent statistics of the device / camera can be accessed by the parameters described in Table 63.

Parameter	Type	Description
ResetAll	CMD	Resets all current statistics
MissingPackets	Integer	Count of missing packets
PacketResendsAmount	Integer	Count of resend requests
LostPackets	Integer	Count of packets that were declared as lost
LostImages	Integer	Count of images that were declared as lost
IgnoredPackets	Integer	Count of packets that are ignored, usually packets that are already analyzed or packets that do not belong to this stream
IncompleteImages	Integer	Count of processed incomplete images

Table 63: Packet Resent statistic parameters

5.1.2 Device Packet Statistics

The *Inter Packet Delay* is usually applied when multiple cameras are connected to one PC over one and the same Network Interface Card (NIC). It enables the user to create a pause between each pair of packets which reduces the amount of effective load and creates timeslots for packets from other devices on the connection.

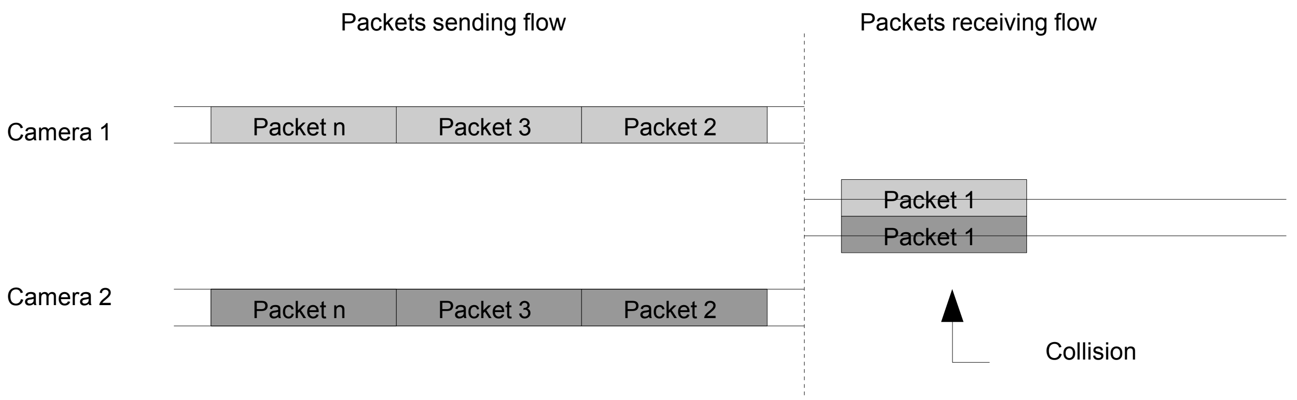


Figure 95: Packet flow while not using inter packet delay

If the *Inter Packed Delay* is not used, excessive collisions between packets may occur which cause in data loss, like illustrated in Figure 95. A number n of packets are sent over the same network connection by two cameras. Without any Inter Packet Delay between the packets, collisions within the packet transmission flow can happen mainly caused by missing bandwidth. Figure 96 illustrates a well configured Inter Packet Delay to prevent collisions.

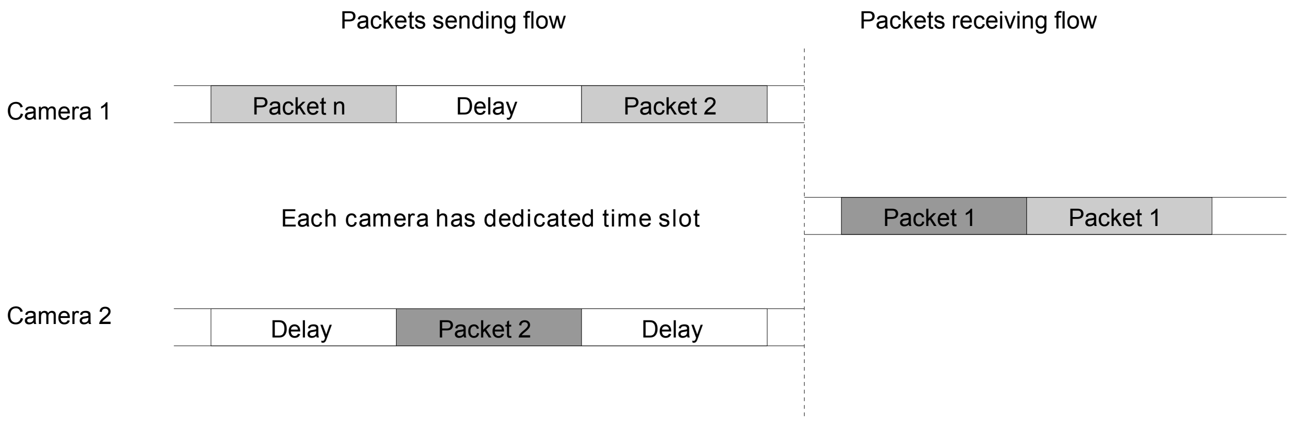


Figure 96: Packet flow while using inter packet delay

Device Packet Statistics

The cameras provide the features *GevSCPSPacketSize* and *GevSCPD*. *GevSCPD* represents the Inter Packet Delay and is expressed in microseconds. Its value can range from 0 to 1000Îijs and should be set according to number of cameras connected to a certain network interface card and *GevSCPSPacketSize*.

The *GevSCPSPacketSize* feature represents the size of packets and is expressed in bytes, the default camera packet size is at 1500 bytes, but can be larger if the network hardware supports Jumbo Frames.

Assuming that the *GevSCPSPacketSize* is 1500 bytes (effective Ethernet packet size including inter-frame gap, preamble, header and CRC on the wire is 1538 bytes), maximum of 81274 packets are sent every second via the Ethernet interface. The time required to transfer one packet is 12,3µs. The *GevSCPD* should be a bit longer than the time required to transfer one packet, in order to ensure that packets from second camera will fit in the vacant time slot. On the other hand, if the camera is producing 60000 packets per second (50 frames per second, 1200 packets per frame), total transfer time must not exceed 16,67µs if frame rate is to be preserved.

Device Packet Statistics

Three cameras are connected to one PC, and are sending 1500 byte packets each. *GevSCPD* should be such that packets from all three cameras are serialized to the PC's Network Interface Card. Setting inter packet delay to 25µs (12,3µs + 12,3µs ≈ 25µs) will ensure that packets from other two cameras will fit in the gap between two consecutive packets.

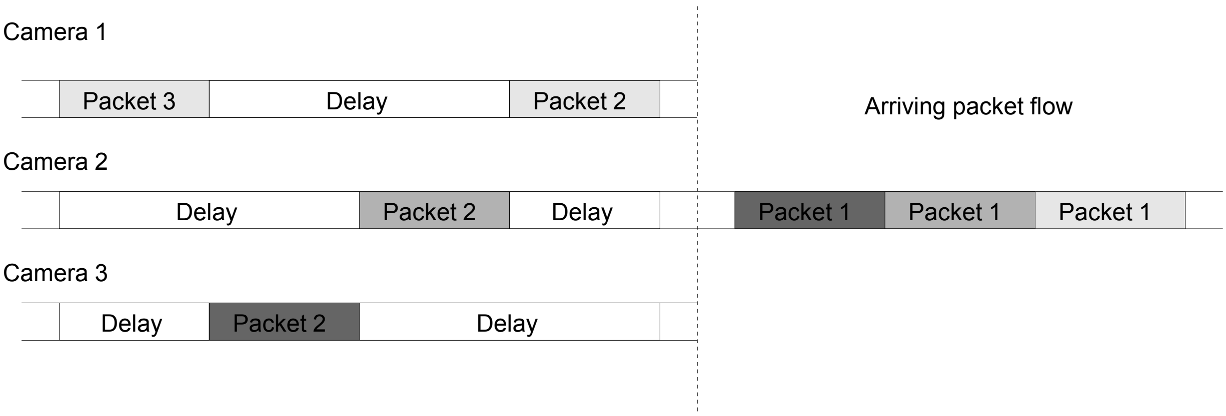


Figure 97: Packet flow example with three cameras and inter packet delay

5.2 LAN IP Configuration

To successfully establish the connection to a camera, the Network configuration needs to be done according to the requirements of the application. The connection of the physical Network Interface Card (NIC) needs to be enabled and set-up properly. Table 64 shows a good configuration for a first start with a single NIC, but does not represent a set definition for all application and network environments.

	NIC (Cameras)	NIC (others)	Camera 1	Camera 2	Camera 3
IP	169.254.0.1	not 169.254.x.x	169.254.1.1	169.254.1.2	169.254.1.x
Subnetmask	255.255.0.0	if 255.255.0.0	255.255.0.0	255.255.0.0	255.255.0.0

Table 64: Basic IP configuration of the PC

Note To using several cameras on multiple Network Interface Cards (NIC) in one PC, make absolutely sure that each NIC is configured for a different network. Otherwise it will not be possible to operate all cameras correctly.

IP Setup in Microsoft Windows

On Microsoft Windows operating systems, the IP can be set up by the following steps:

1. Execute "ncpa.cpl", e.g. via the command box of the Windows *Startmenu* or after pressing + R on your keyboard
2. Right-click the target network interface card and choose *Properties*.
3. Choose the *Internet Protocol Version 4 (TCP/IPv4)* entry in the list of protocols.
4. By default the interface is configured to obtain an IP address automatically by a DHCP server, shown in Figure 98, usually provided by routers or dedicated servers. A fixed IP address and Subnet mask can be entered like shown in Figure 98 right, after choosing *Use the following IP address*.

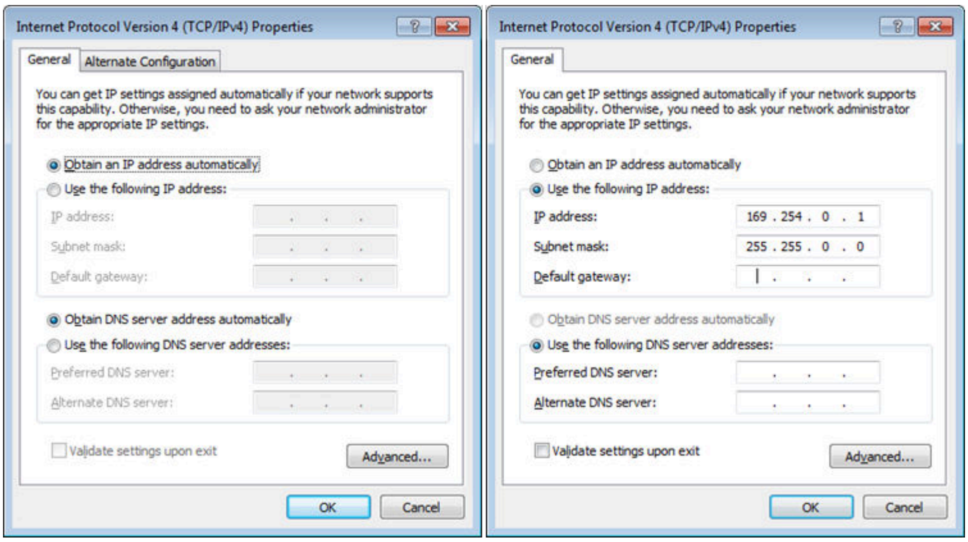


Figure 98: Internet Protocol Version 4 (TCP/IPv4) properties

5.3 Network Interface Optimization

To reach the optimal performance with the Giganetix cameras, the right choice of hardware is crucial, as well as its configuration. All following descriptions of driver settings are based on the Intel® network driver interface on Microsoft Windows, the availability of each feature and its limits can differ between hardware vendors and operating systems.

5.3.1 Choosing the right Network Interface Card

The first step is to choose the right network interface card (NIC). It is strongly recommended to use *PCI Express* based Gigabit Ethernet NICs supporting so called *Jumbo Frames* or *Jumbo Packages*. NICs based on the old interface standard *PCI* do often not provide enough guaranteed bandwidth due to the limited and shared bandwidth of the *PCI* bus. However, the *PCI Express* bus provides guaranteed enough bandwidth for Gigabit Ethernet. Jumbo frames reduce the overhead and workload on the target PC, reducing the amount of packets to be processed by sending a smaller count of larger packets instead of a high count of small packets. A good choice are NICs with the Intel® Pro/1000 chipset, like the Intel® Pro/1000 CT Desktop (single port) or PT Server Adapter (multiport).

Note

Jumbo packets / frames need to be supported by the NIC as well as the whole network chain, including all network switches passed on the route.

5.3.2 Using Jumbo Frames / Packets

As soon as Jumbo Frames / Packets are supported by the network infrastructure, it has to be made sure that this feature is enabled on each involved device. Devices like NICs have this feature usually disabled by default as well as some managed switches, what makes it suggestive to throw a look into their configuration.

Network Interface Card (NIC)

For NICs it is usually necessary to enable the Jumbo Frame / Packet feature manually within the device driver.

On Microsoft Windows operating systems this can be accessed on the following way:

1. Execute "ncpa.cpl", e.g. via the command box of the Windows *Startmenu* or after pressing + R on your keyboard
2. Right-click the target network interface card and choose *Properties*.
3. Press the *Configure* button below the name of the physical network interface, shown in Figure 99.

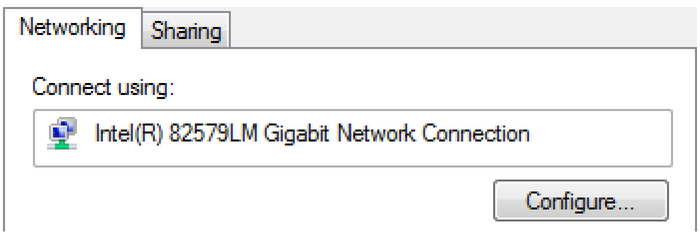


Figure 99: Access to network interface card driver settings

4. The settings of the driver can be accessed by choosing the *Advanced* tab of the opened window. As shown in Figure 100, raise the value of the *Jumbo Packet* property to its maximum value.

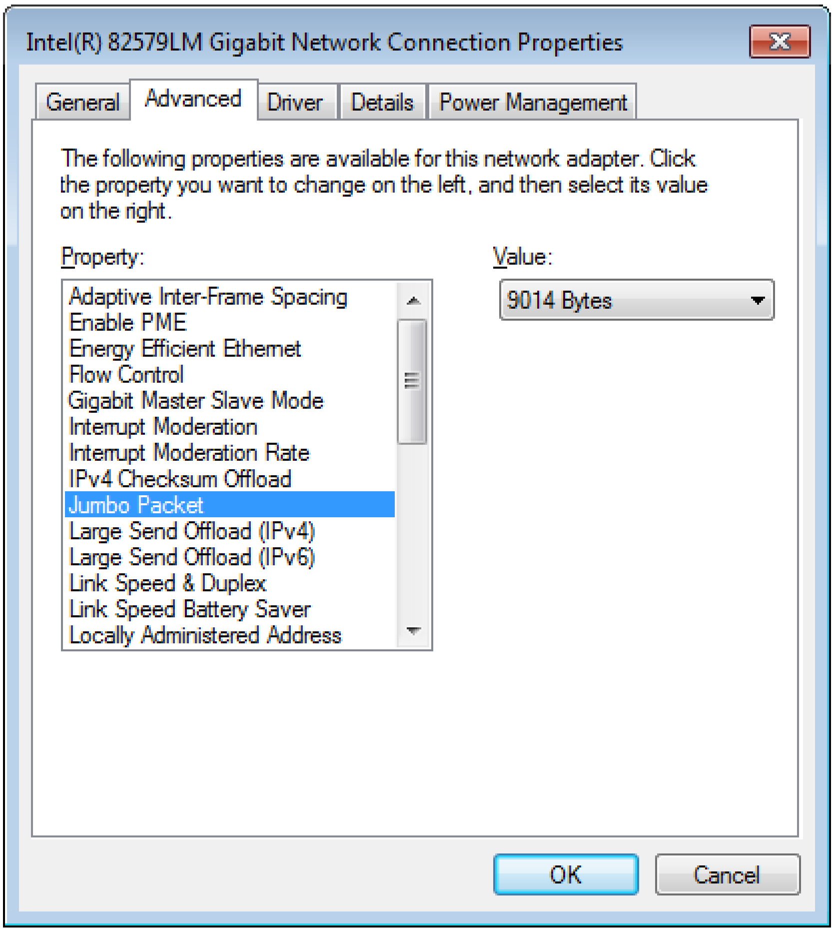


Figure 100: Network interface card - advanced driver settings - Jumbo Packets

Gigabit Ethernet Switches

Standard or simple network switches (unmanaged) which support Jumbo Frames / Packets usually have this feature enabled per default, as they offer no way of configuration. Professional or so called managed switches, which provide a configuration interface (in most cases with a web based GUI), have it in many cases disabled as it is configurable for each port separately. For validation please refer to the documentation of your individual device.

5.3.3 Raising Receive Buffers

The receive buffer size of the network interface card represents a reserved memory in the system memory, which is used to buffer incoming data. Especially at the high bandwidth of Gigabit Ethernet cameras, it is recommended to raise the buffer size for at least the incoming packets (receive buffers) to the supported maximum. As it is a feature of the network interface card, it usually can be accessed via its driver settings.

On Microsoft Windows operating systems it can be accessed on the following way:

1. Execute "ncpa.cpl", e.g. via the command box of the Windows *Startmenu* or after pressing + R on your keyboard
2. Right-click the target network interface card and choose *Properties*.
3. Press the *Configure* button below the name of the physical network interface, shown in Figure 99.
4. The settings of the driver can be accessed by choosing the *Advanced* tab of the opened window. As shown in Figure 101, raise the value of the *Receive Buffers* property to its maximum value.

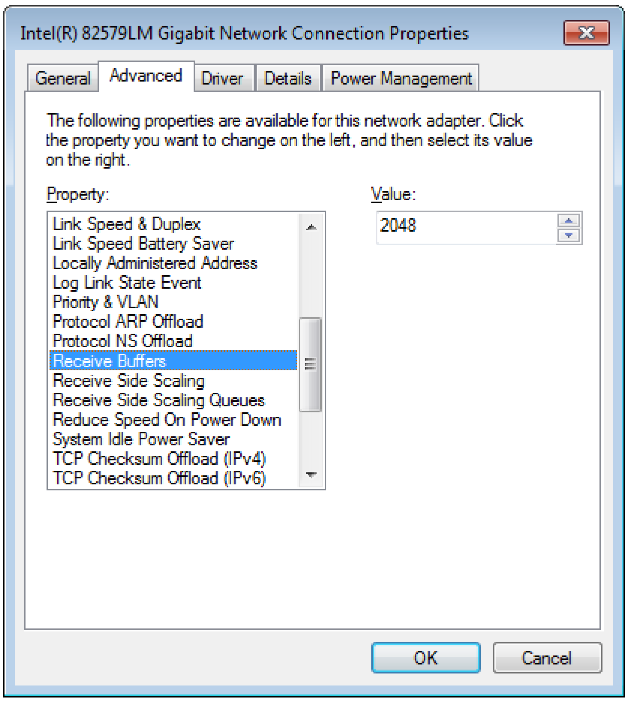


Figure 101: Network interface card - advanced driver settings - Receive Buffers

5.3.4 Disable the Interrupt Moderation Rate

To optimize the latency of the data transmission, it is recommended to disable the *Interrupt Moderation Rate* feature of the network adapter. This feature changes the way of interrupt generation by an incoming packet and makes it possible to reduce the delay in the processing of incoming Ethernet packets. It is usually accessible via the identically named property in the advanced driver settings of the NIC, shown in Figure 102.

On Microsoft Windows operating systems it can be accessed on the following way:

1. Execute "ncpa.cpl", e.g. via the command box of the Windows *Startmenu* or after pressing + R on your keyboard
2. Right-click the target network interface card and choose *Properties*.
3. Press the *Configure* button below the name of the physical network interface, shown in Figure 99.
4. The settings of the driver can be accessed by choosing the *Advanced* tab of the opened window. As shown in Figure 102, set the value of the *Interrupt Moderation Rate* property to *Off* or *Disabled*.

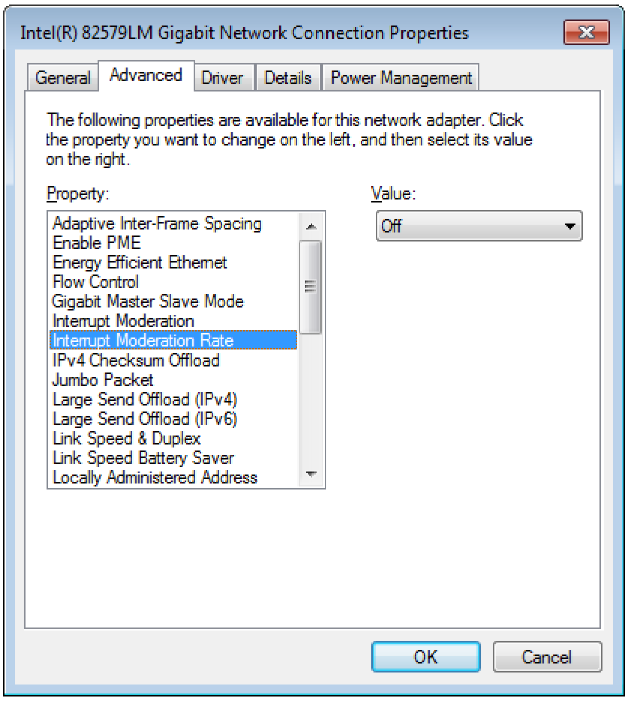


Figure 102: Network interface card - advanced driver settings - Interrupt Moderation Rate

5.3.5 Disable the Flow Control

To further optimize the latency of the data transmission, shown in *5.3.4 - Disable the Interrupt Moderation Rate*, it is possible to disable the so called *Flow Control*. The *Flow Control* is a feature to adapt the transmission speed of the transmitter to the speed available at the receiver by sending PAUSE frames in-between.

Note As deactivating this feature can cause in packet lost due to missing bandwidth, it is generally not recommended to be disabled!

On Microsoft Windows operating systems the Flow Control can be accessed on the following way:

1. Execute "ncpa.cpl", e.g. via the command box of the Windows *Startmenu* or after pressing + R on your keyboard
2. Right-click the target network interface card and choose *Properties*.
3. Press the *Configure* button below the name of the physical network interface, shown in Figure 99.
4. The settings of the driver can be accessed by choosing the *Advanced* tab of the opened window. As shown in Figure 103 , set the value of the *Interrupt Moderation Rate* property to *Disabled*.

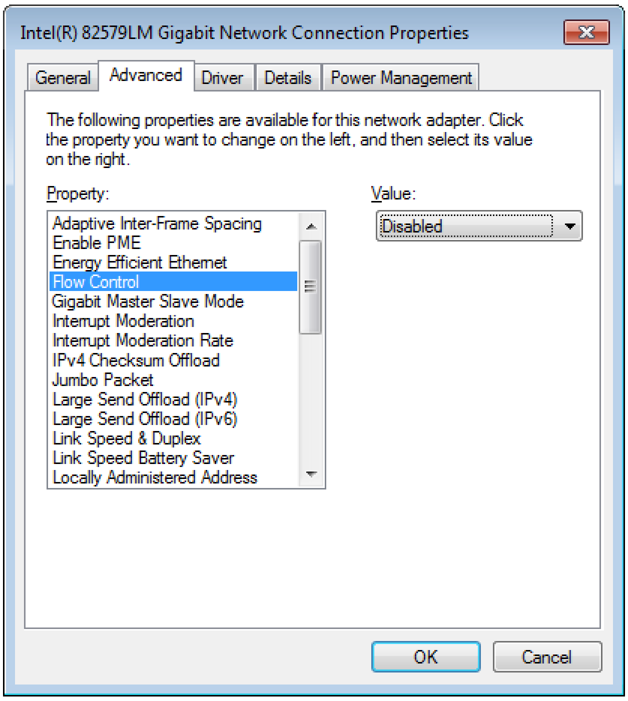


Figure 103: Network interface card - advanced driver settings - Flow Control

5.4 Digital Image and Pixel Formats

This section describes pixel and image layouts supported by SMARTEK Vision digital cameras. While a pixel format describes how a single pixel data is constructed, the image layout represents how the data are ordered in the memory of the captured device. It is identical for all cameras.

5.4.1 Image Layout

Figure 104 shows the image layout valid for all SMARTEK Vision digital cameras. An image transmitted out of a camera is considered to be a two-dimensional array of pixels. The pixels are stored in subsequent addresses in the memory of the capture device, usually a PC. Each pixel, depending on its format, is either 8 bits or 16 bits wide. It is described by two indices; the first index indicates the row while the second index indicates the column where the pixel is located:

- P(x, y) means the pixel located at row x and at column y.
- P(1, 1) means the pixel located at row 1 and at column 1.
- P(1, 2) means the pixel located at row 1 and at column 2.

An image with a width of **w** and a height of **h** starts at the upper left corner and ends at the bottom right corner. P(1, 1) is the first pixel of the image, P(h, w) is the last pixel of the image.

column →

row ↓

$P_{(1,1)}$	$P_{(1,2)}$	$P_{(1,3)}$	…	$P_{(1,w-2)}$	$P_{(1,w-1)}$	$P_{(1,w)}$
$P_{(2,1)}$	$P_{(2,2)}$	$P_{(2,3)}$	…	$P_{(2,w-2)}$	$P_{(2,w-1)}$	$P_{(2,w)}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮
$P_{(h-1,1)}$	$P_{(h-1,2)}$	$P_{(h-1,3)}$	…	$P_{(h-1,w-2)}$	$P_{(h-1,w-1)}$	$P_{(h-1,w)}$
$P_{(h,1)}$	$P_{(h,2)}$	$P_{(h,3)}$	…	$P_{(h,w-2)}$	$P_{(h,w-1)}$	$P_{(h,w)}$

Figure 104: Image layout and transmission sequence

The subsequent sections will describe all the supported formats for each pixel P in an image, for monochrome cameras as well as color cameras.

5.4.2 Supported Pixel Formats for Monochrome Cameras

5.4.2.1 Mono8

In an image with the pixel format Mono8 each pixel value P is represented by one byte or 8 bits. The Mono8 pixel format in SMARTEK Vision digital cameras is specified as shown below:

PixelFormat	Mono8
Description	8-bit monochrome unsigned
Pixel size	1 byte
Value range	0 . . . 255

Table 65: Specification PixelFormat Mono8

The memory layout of the image with *Mono8* pixel format is shown in Figure 105 . Starting from the upper left of the image, byte 0 represents the value of pixel P(1, 1), byte 1 represents the value of pixel P(1, 2) and so on. In each byte the bitorder is by default little endian; the least significant bit is assigned to bit 0 and the most significant bit to bit 7.

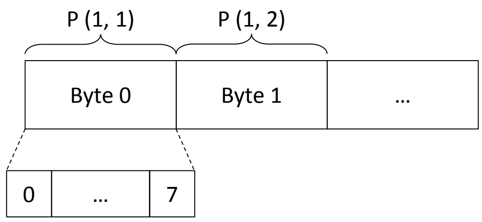


Figure 105: Image layout with pixel format Mono8

5.4.2.2 Mono16

In an image with pixel format *Mono16* each pixel value P is represented by two bytes or 16 bits. The *Mono16* pixel format in SMARTEK Vision digital cameras is specified as shown below:

PixelFormat	Mono16
Description	16-bit monochrome unsigned
Pixel size	2 byte
Value range	0 . . . 65535

Table 66: Specification PixelFormat Mono16

The two bytes are arranged in little-endian order, which means that the Least Significant Byte (LSB) is arranged first, the most significant byte second. The memory layout of the image with the Mono16 pixel format is shown in Figure 106. Starting with the upper left of the image, byte 0 and byte 1 represent the value of pixel P(1, 1), byte 2 and byte 3 represent the value of pixel P(1, 2) and so on. The least significant bit is assigned to bit 0 of the first byte, the most significant bit to bit 7 of the second byte.

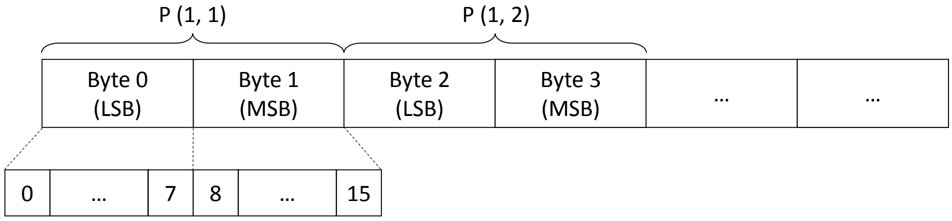


Figure 106: Image layout with pixel format Mono16

5.4.3 Supported Pixel Formats for Color Cameras

5.4.3.1 BayerGR8 / BayerRG8 / BayerGB8 / BayerBG8

In an image with one of the *Bayer8* pixel formats, each pixel value P is represented by one byte or 8 bits. The "GR", "RG", "GB" or "BG" notation describes the layout of the Bayer pattern on the image sensor, used in the camera. For detailed description about color imaging and the Bayer filter, please refer to chapter *4.1.5 - Color Imaging with Bayer Pattern*.

The *Bayer8* pixel formats in SMARTEK Vision digital cameras are specified like shown below:

PixelFormat	**BayerGR8, BayerRG8, BayerGB8, BayerBG8**
Description	8-bit monochrome unsigned
Pixel size	1 byte
Value range	0 . . . 255

Table 67: Specification PixelFormat Bayer8

The memory layout of the image with this pixel formats is shown in Figure 107. Starting from the upper left of the image, byte 0 represents the value of pixel P(1, 1), byte 1 represents the value of pixel P(1, 2) and so on. In each byte the bitorder is by default little endian; the least significant bit is assigned to bit number 0 and the most significant bit is assigned to bit number 7.

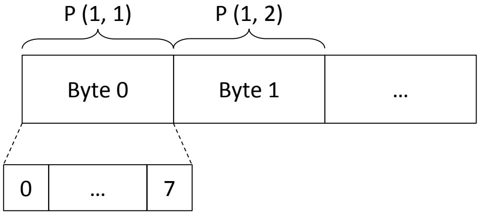


Figure 107: Image Layout with pixel format GR8/RG8/GB8/BG8

5.4.3.2 BayerGR16 / BayerRG16 / BayerGB16 / BayerBG16

In an image with pixel format *Bayer16* each pixel value P is represented by two byte or 16 bits. The "GR", "RG", "GB" or "BG" notation describes the Bayer pattern of the image sensor used in the camera. For detailed description about the Bayer filter, please refer to chapter 4.1.5 - Color Imaging with Bayer Pattern. The *Bayer16* pixel format in SMARTEK Vision digital cameras is specified like shown below:

PixelFormat	BayerGR16, BayerRG16, BayerGB16, BayerBG16
Description	16-bit monochrome unsigned
Pixel size	2 byte
Value range	0 . . . 65535

Table 68: Specification PixelFormat Bayer16

The two bytes are arranged in little-endian order, which means the Least Significant Byte comes first, the most significant byte comes second. The memory layout of the image with the *Bayer16* pixel format is shown in Figure 108. Starting from the upper left of the image, byte 0 and byte 1 represent the value of pixel P(1, 1), byte 2 and byte 3 represent the value of pixel P(1, 2) and so on. The least significant bit is assigned to bit 0 of the first byte, the most significant bit to bit 7 of the second byte.

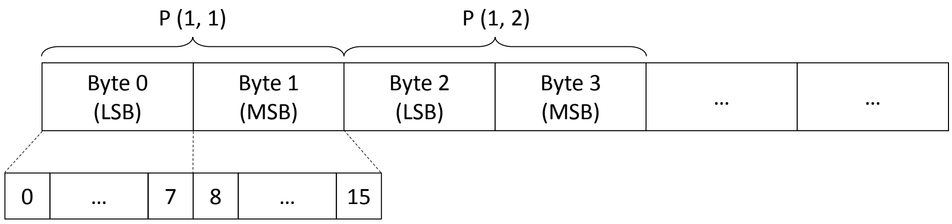


Figure 108: Image layout with pixel format GR16/RG16/GB16/BG16

5.4.4 Pixel Formats Supported by the SMARTEK Vision Giganetix camera family

Monochrome Cameras

CMOS	Mono8	Mono16
GC1281M	●	○
GC2591M	●	○
GC3851M	●	○
CCD	**Mono8**	**Mono16**
GC651M	●	●
GC652M	●	●
GC653M	●	●
GC781M	●	●
GC1031M	●	●
GC1291M	●	●
GC1391M	●	●
GC1392M	●	●
GC1621M	●	●
GC2441M	●	●
GC1021M	●	●
GC1601M	●	●
GC1921M	●	●
GCP1941M	●	●
GCP2751M	●	●
GCP3381M	●	●

Table 69: Pixel formats supported by SMARTEK Vision monochrome cameras

Color Cameras

CMOS	BayerGR8	BayerGR16	BayerRG8	BayerRG16
GC2041C	●	○	○	○
GC2591C	●	○	○	○
GC3851C	●	○	○	○
CCD	**BayerGR8**	**BayerGR16**	**BayerRG8**	**BayerRG16**
GC651C	○	○	●	●
GC652C	○	○	●	●
GC653C	○	○	●	●
GC781C	○	○	●	●
GC1031C	○	○	●	●
GC1291C	○	○	●	●
GC1391C	○	○	●	●
GC1392C	○	○	●	●
GC1621C	○	○	●	●
GC2441C	○	○	●	●
GC1021C	●	●	○	○
GC1601C	●	●	○	○
GC1921C	●	●	○	○
GCP1941C	○	○	●	●
GCP2751C	●	●	○	○
GCP3381C	○	○	●	●

Table 70: Pixel formats supported by SMARTEK Vision color cameras

Note — On dual tap CCD camera models, 16 bit pixel formats are supported by the means of firmware update. There are two different firmware versions for those camera models: one supporting 8 bit pixel formats and the other supporting 16 bit pixel formats.

Note — The 16 Bit formats of SMARTEK Vision Giganetix cameras contain the full, in chapter 2.2 - Sensor Information and Technical Specification (All Models Separate) specified, bit depth available by the sensor. As this are in most cases less than 16 Bit of payload, the effective image data is aligned to the Most Significant Bits (MSB).

6 Image Processing in GigEVisionSDK

The *ImageProcAPI* provided by the *GigEVisionSDK* extends the camera functionality and provides a comprehensive set of fundamental image operations and image processing algorithms, including White Balancing, Gamma Correction, Demosaicing, Color Correction and many more. All programming languages supported by the *GigEVisionSDK* API are supported by the *ImageProcAPI* as well, namely C/C++, Delphi, C# and VB .NET.

Table 71 lists all image processing algorithms implemented in the *ImageProcAPI* including the supported input image type.

	Supported image input type		
Image statistics	**Monochrome**	**Raw Bayer**	**RGB**
Histogram	✓	✓	✓
Average luminance	✓	✓	✓
Image processing algorithms			
Look-up Table (LUT)	✓	✓	✓
Digital Gain	✓	✓	✓
Auto Exposure	✓	✓	✓
White Balance		✓	✓
Gamma Correction	✓	✓	✓
Debayering / Demosaicing			
Bilinear		✓	
High-Quality Linear		✓	
Pixel Grouping		✓	
Colorized		✓	
Matrix Multiplication			✓
Gimp HSL			✓
Sharpening	✓		✓
RGB to Gray conversion			✓
Bit Depth conversion	✓	✓	✓
Image Processing pipeline			
Color pipeline	✓	✓	

Table 71: Implemented image processing algorithms in ImageProcAPI

The installed *ImageProcAPI* includes several code examples for reference, available in all supported programming languages. All examples are located in the corresponding folder of the *GigEVisionSDK* installation directory. For a more detailed description on the parameters of each algorithm or on how to apply them, please refer to the *GigEVisionSDK* API help located at the doc folder of the *GigEVisionSDK* installation directory.

6.1 Image Statistics

6.1.1 Histogram

A histogram is a graphical representation of the distribution of all intensity values that can be found in an image. The histogram graph is plotted using the Cartesian coordinate system. The x-coordinates are in a range from 0 to 2^n - 1, where n is the bit depth of a pixel value. Each x-coordinate can correspond to an intensity value that exists in the image. The y-coordinates are in a range from 0 to *image_width* x *image_height*, describing the total numbers of pixels for each pixel value found in the image.

Figure 109 illustrates a histogram of an 8-bit monochrome image (1):

- The horizontal x-axis of the graph (2) contains the intensity values with a range from 0 to 2^8 - 1, or 0 to 255. The vertical y-axis shows the count of pixels with the corresponding intensity. There are 5774 pixels that have the value 80 in the image (1) for example.
- While the graph (2) allows a quick visual interpretation of the distribution of pixels in the image, the histogram table (3) gives more exact information about the count of specific intensities. For the pixel value 80 there are exact 5774 pixels located in the image while other intensity levels, are not even present, like 1 and 2.

Pixel value	Count
0	768
1	0
2	0
…	…
80	5774
81	4535
…	…
255	1191

Histogram table

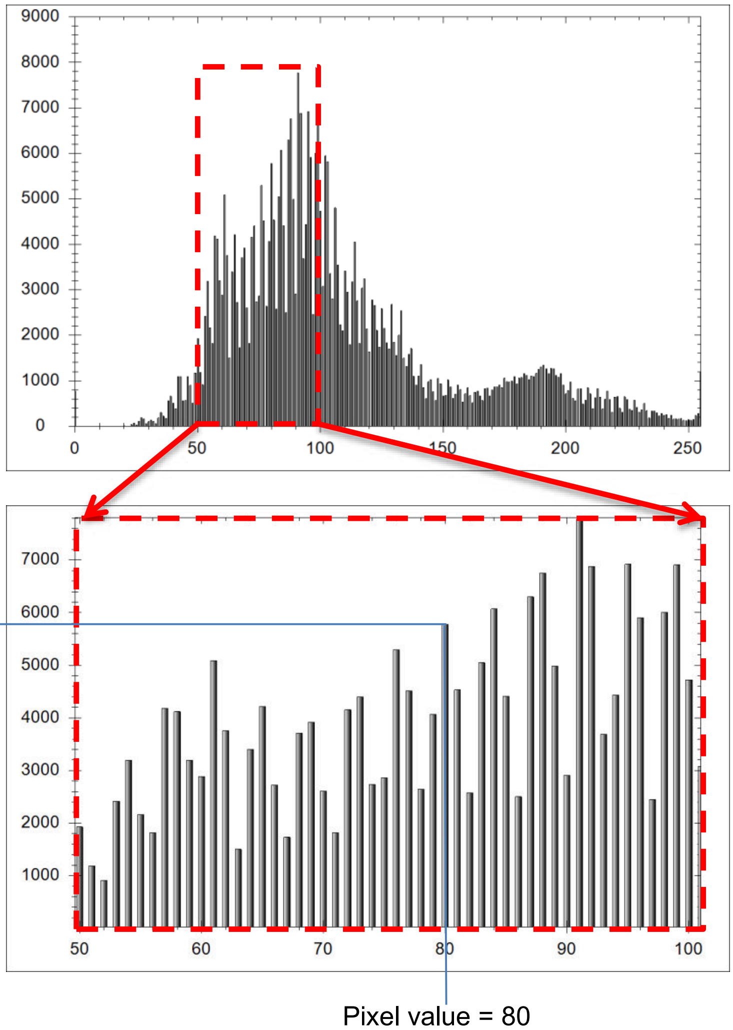
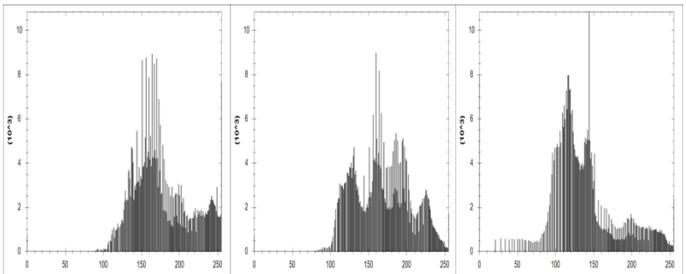


Figure 109: Source image with histogram graph and table

Histogram calculation can be applied to monochromatic or RGB image data. The number of resulting histograms corresponds to the number of channels. In the previous example there is only a single histogram for the monochrome image. However, on RGB color images are three histograms generated, each represents a single color channel (red, green and blue), illustrated in Figure 110. The application of histograms is varying; on the basis of a histogram and depending on the scene the user can for example quickly determine whether the captured image is over-, under- or normal-exposed. Figure 110 shows three color images with the corresponding histograms for each channel. Without looking to the images, the following information can be determined by the histogram:

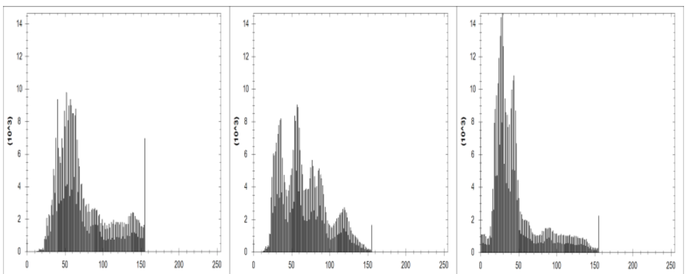
- In the first row the population of the pixel values in each histogram is shifted to the right of the center (brighter region); it indicates an overexposed image.
- In the second row the three histograms are shifted to the left (darker region); it indicates an underexposed image.
- In the third and last row the three histograms show a centered uniform distribution of pixel intensities; it indicates an optimal exposed image.

Overexposed Image



Histogram of red channel | Histogram of green channel | Histogram of blue channel

Underexposed Image



Histogram of red channel | Histogram of green channel | Histogram of blue channel

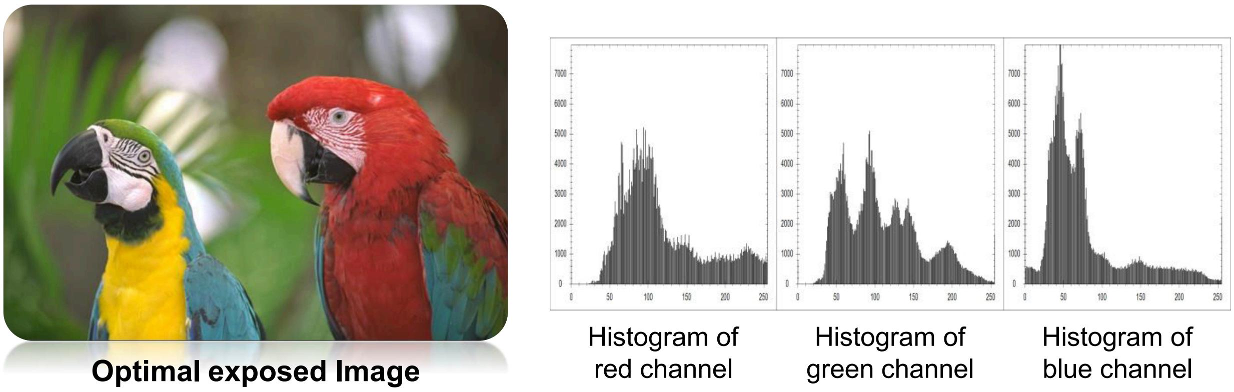


Figure 110: Example of using histogram to determine optimal image exposure

Other applications for histograms are:

- Calculation of optimal exposure time
- Calculation of correction values for white balancing
- Contrast enhancement using histogram equalization
- Global thresholding (often used in the area of image segmentation)

Histogram in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface to generate histogram data from images. The bit depth and image types supported by the histogram feature are shown in Table 72. For a detailed description on how to instantiate this feature in user applications please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 72: Histogram - supported bit depth and image types

Histogram in the GigEVisionClient

In the *GigEVisionClient* application the histogram feature can be enabled by the menu bar entry Control ⇒ Histogram, shown in Figure 111.

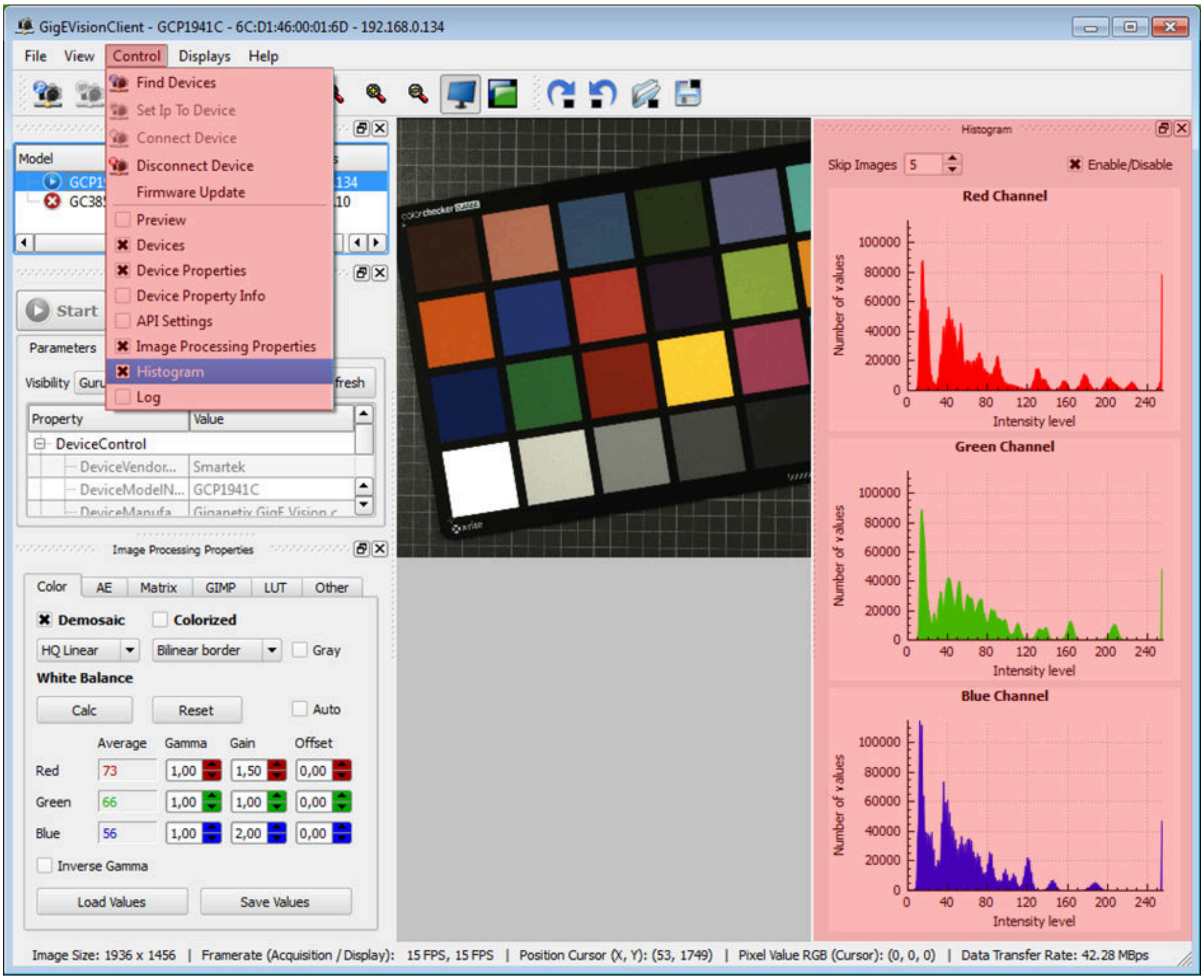


Figure 111: Histogram feature in GigEVisionClient

- **Skip Images (default 5)**: Number of frames to skip before a new histogram is calculated and the GUI is updated.
- **Enable / Disable:** Active / deactivate histogram calculation.

6.1.2 Average Luminance Calculation

The Average Luminance algorithm sums up all pixel values on each channel of an image and calculates the average value by dividing the sum of pixel values by number of pixels on this channel:

$$\text{Averagevalue}_{\text{channel}} = \frac{\sum \text{Pixelvalue}_{\text{channel}}}{\text{Totalpixels}_{\text{channel}}}$$

For single channel images only one average value is calculated, while for raw/color images each channel has its own value.

Calculating average values of an image is a fundamental operation in image processing and serves as a basis calculation for algorithms like auto exposure and auto white balancing.

Average Luminance Calculation in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface to generate average luminance data of an image. The bit depth and image type supported are shown in Table 73. For a detailed description on how to use the average value calculation feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 73: Average luminance calculation - supported bit depth and image types

Average Luminance in the GigEVisionClient

Calculated average value(s) of the image channel(s) can be found in the *Image Processing Properties* under *Color / Mono*, shown in Figure 112. If not visible, it can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

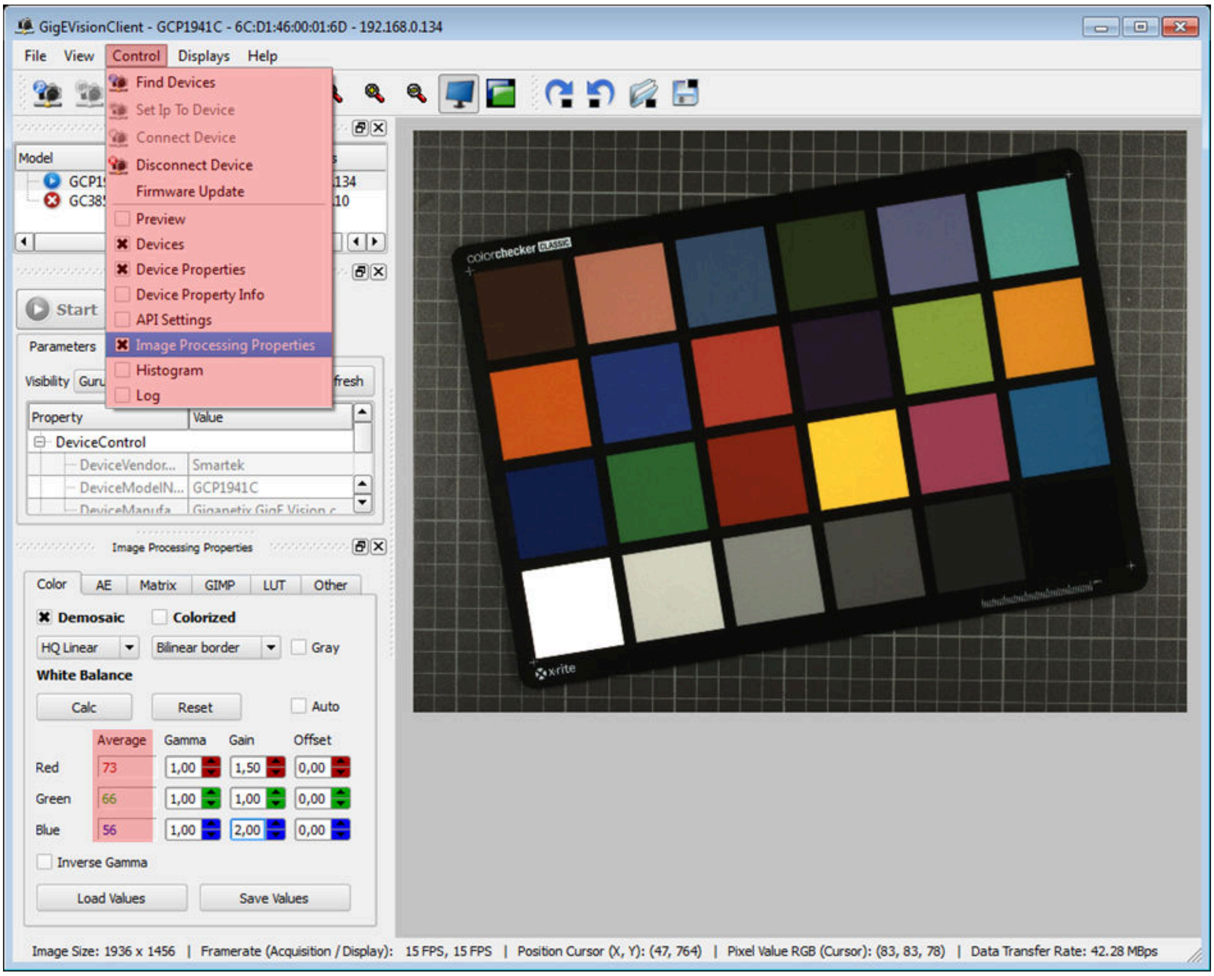


Figure 112: Average value calculation in GigEVisionClient for White Balancing algorithm

6.2 Image Processing Algorithms

6.2.1 Luminance Look-Up Table (LUT)

In image processing a Look-Up Table or LUT is used to transform input pixel values into desired output pixel values by using mapping operations.

Essentially a luminance look-up table is a list with 2^n entries, where n is the bit depth of the input image. Each entry in the table has an index and represents an output luminance value. The indices are unique and numbered continuously from 0 to 2^{n-1}. Figure 113 shows an example of an 8 bit look-up table.

Lookup table

index	value
0	0
1	20
2	28
3	33
...	...
253	254
254	254
255	255

input 3 → 3 | 33 → output

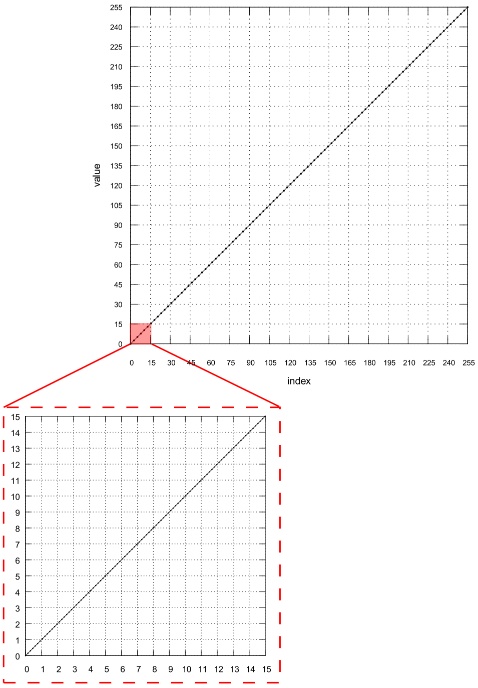
Figure 113: 8 bit look-up table

The index represents the luminance of a pixel in the image, which is exchanged by the value:

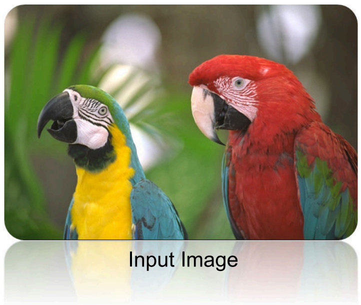
- When an input pixel value has a value of 1, this value will be used as the index in the table. The corresponding 8 bits output pixel value at index 1 will be 20.
- When an input pixel value has a value of 3, this value will be used as the index in the table. The corresponding 8 bits output pixel value at index 3 will be 33.
- When an input pixel value has a value of 253, this value will be used as the index in the table. The corresponding 8 bits output pixel value at index 253 will be 254.

Look-up tables are especially suited for point operations in image processing where output pixel values depend only on the corresponding input pixel values. In the following a couple of application examples using look-up tables are shown.

The first example shows a look-up table where each output pixel value is mapped to its exactly corresponding input pixel value. The look-up table is a linear function (f(x) = x) and its graph is a 45° straight line, shown in Figure 114. Because of the one-to-one value mapping the output image is identical to the input image.



index	value
0	0
1	1
2	2
…	…
126	126
127	127
128	128
…	…
253	253
254	254
255	255



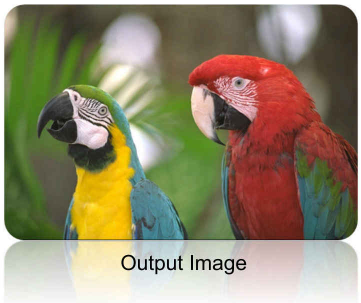
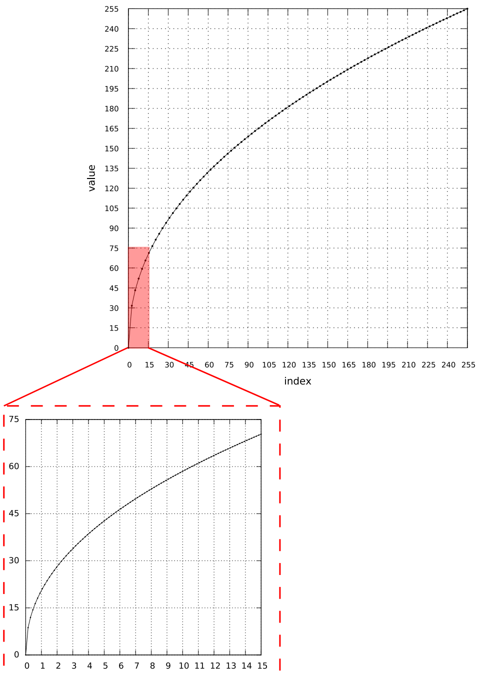
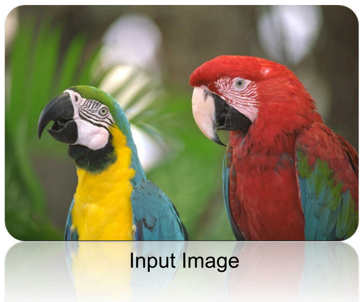


Figure 114: Linear transformation using 8 bit look-up table

The second example demonstrates a variant of gamma correction using a look up table. By reference to the look-up table and its corresponding graph, in Figure 115, it is visible that a non-linear transformation is applied to the input pixel values.



index	value
0	0
1	20
2	28
…	…
126	185
127	185
128	186
…	…
253	254
254	254
255	255



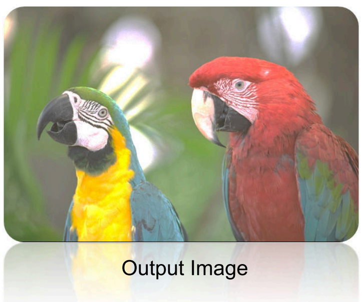
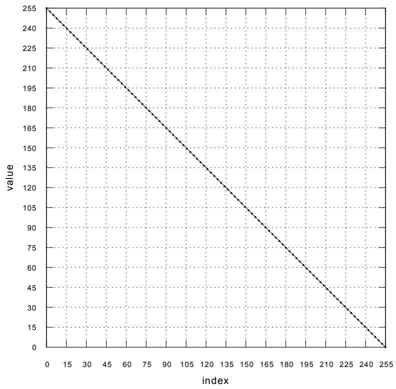


Figure 115: Gamma correction using look-up table

The third example, illustrated in Figure 116, shows the inverting of an 8 bit monochrome image by a LUT. Every input gray level value is transformed into an output gray-level value by the formula $\mathrm{Value}_{\mathrm{out}} = 2^8 - \mathrm{Value}_{\mathrm{in}}$.



index	value
0	255
1	254
2	253
...	...
126	129
127	128
128	127
...	...
253	2
254	1
255	0

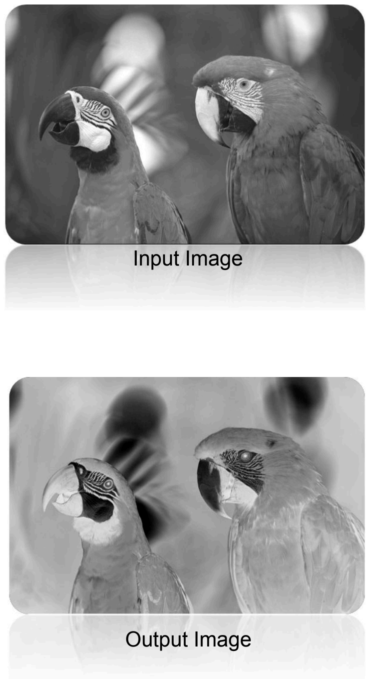
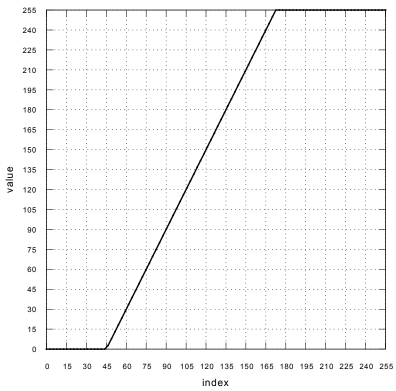


Figure 116: Inverting a monochrome image using look-up table

The last example demonstrates two implementations of contrast enhancement, using a look-up table applied to an 8-bit per channel color image. In Figure 117 the first 45 pixel values have been set to 0 and pixel values in range from 173 to 255 have been set to 255.



index	value
0	0
1	0
2	0
...	...
126	162
127	164
128	166
...	...
253	255
254	255
255	255

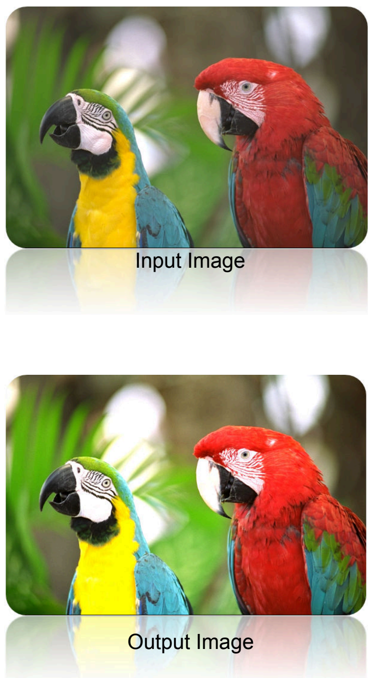
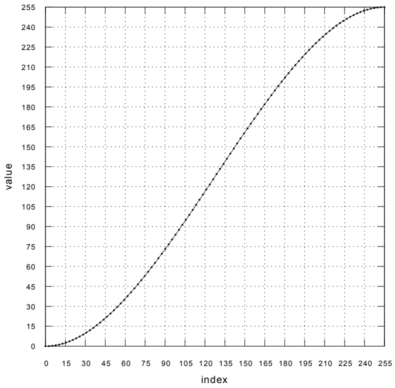


Figure 117: Enhancing contrast of an image using look-up table

Figure 118 shows the same purpose by a complex function and illustrates that the implemented algorithms can be arbitrarily complex. However, the calculation for generating look-up tables will be executed only once.



index	value
0	0
1	0
2	0
...	...
126	126
127	127
128	128
...	...
253	255
254	255
255	255

Figure 118: Example 2 of enhancing contrast of an image using look-up table

Look-up table in GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for generating and modifying look-up tables. The bit depth and image type supported are shown in Table 74. For a detailed description on how to use the look-up table feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 74: Look-up table - supported bit depth and image types

Look-up table in GigEVisionClient

The *GigEVisionClient* provides the user the ability to load a pre-defined look-up table in form of an *XML* file into the application. XML examples for look-up tables are located in the *GigEVisionSDK* installation folder:

$(GIGE_VISION_SDK_PATH)\GenICam_v2_4\xml\custom\

```xml
<?xml version="1.0" encoding="UTF-8"?>
<values>
    <color channel="Red">
        <LUT index="0" value="230"/>
        <LUT index ="1" value="57"/>
        <LUT index ="2" value="28"/>
               ...
        <LUT index ="254" value="72"/>
        <LUT index ="255" value="67"/>
    </color>
    <color channel="Green">
        <LUT index ="0" value="208"/>
        <LUT index ="1" value="96"/>
        <LUT index ="2" value="253"/>
               ...
        <LUT index ="254" value="231"/>
        <LUT index ="255" value="42"/>
    </color>
    <color channel="Blue">
        <LUT index ="0" value="206"/>
        <LUT index ="1" value="74"/>
        <LUT index ="2" value="146"/>
        ...
        <LUT index ="254" value="250"/>
        <LUT index ="255" value="182"/>
    </color>
</values>
```

```xml
<?xml version="1.0" encoding="UTF-8"?>
<values>
    <color channel="Luminance">
        <LUT index ="0" value="230"/>
        <LUT index ="1" value="57"/>
        <LUT index ="2" value="28"/>
               ...
        <LUT index ="254" value="72"/>
        <LUT index ="255" value="67"/>
    </color>
</values>
```

Figure 119: User-defined XML file for 8 Bit RGB color (left) or monochrome (right) images

Figure 119 shows an example of a properly formatted XML file which contains look-up table parameters for 8-bit per channel color and monochrome images. The first line indicates the root element values. Element color with attribute channel indicates the channel for which the parameters will be set. The Child element LUT with the attribute index indicates the index or input value, the attribute value indicates the output value for the current index.

Figure 120 shows the look-up table feature located in the *LUT* tab within the *Image Processing Properties* panel. If not visible, the *Image Processing Properties* panel can be activated by the menu bar entry *Control* ⇒ *Image Processing Properties*.

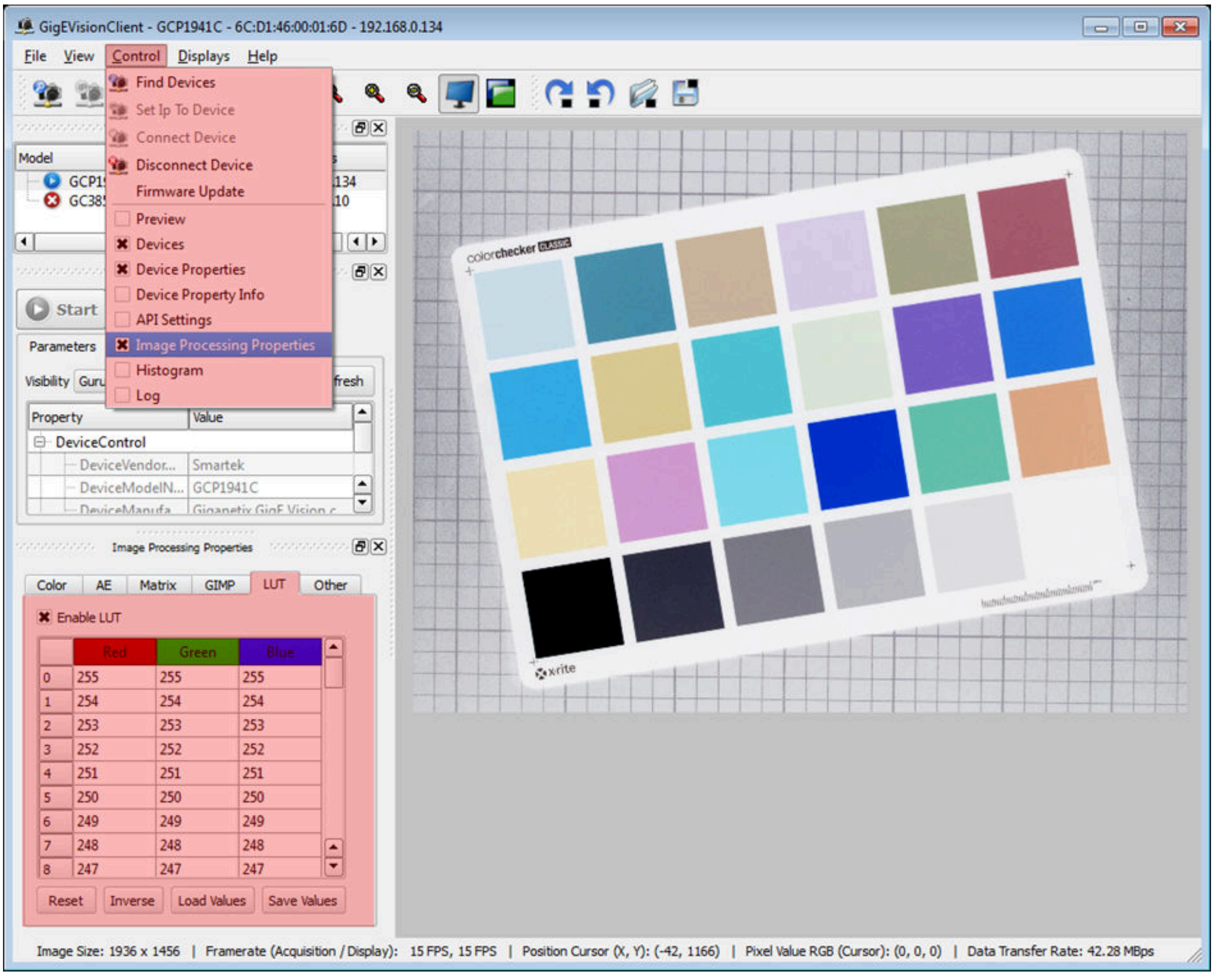


Figure 120: Look-up table feature in GigEVisionClient

- **Enable LUT:** Enable application of look-up table
- **Reset:** Reset look-up table to default values
- **Load Values:** Load an user-defined XML file with look-up table parameters into the client
- **Save Values:** Save the user-defined look-up table to a file
- **Inverse:** Generate a predefined look-up table which inverts the image

6.2.2 Digital Gain

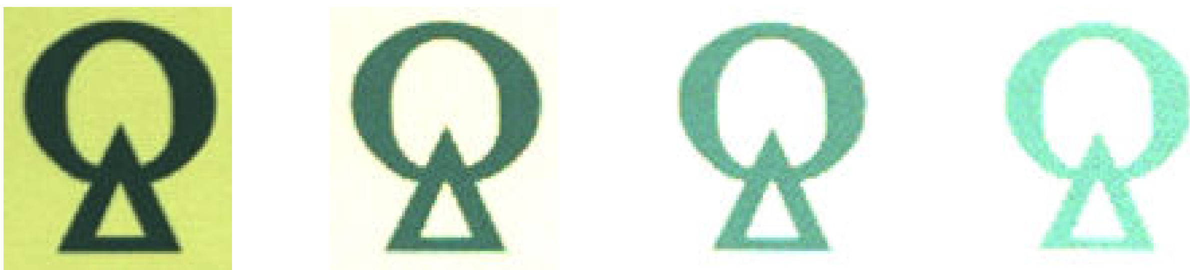
The pixel signal received from an image sensor is amplified and digitized before transmitted to the host application. For devices which do not provide an individual analog gain separately for each color channel, or in applications where the available maximum analog gain does not suffice, a software based gain can be applied by the *ImageProcAPI*. The digital gain is a factor which is multiplied with each pixel value of an image channel, generating the new value of the pixel:

$$\mathrm{Pixel}(x,y)_{\mathrm{out}} = \mathrm{Pixel}(x,y)_{\mathrm{In}} \times \mathrm{DigitalGain}$$

Each channel has its own gain value, which makes it for example to a tool for white balancing, if not already supported by the camera.

Further, digital gain is a useful feature to enhance the image brightness, especially under low light condition. Increasing a digital gain value means increasing the intensity of each pixel, resulting in a brighter overall image. However, the image noise will also be increase with digital gain.

Figure 121 demonstrates four different gain settings applied to the image. While digital gain equals 1.0 represents the image at its original, with increasing digital gain value, the image becomes brighter and the noise rises as well. Also at higher gain settings, some pixels are over-saturated what leads to information loss in the image.



Digital Gain = 1.0 *Digital Gain = 2.0* *Digital Gain = 3.0* *Digital Gain = 4.0*

Figure 121: Digital Gain to brighten an image

Note

In contrast to the analog gain the digital gain produces "holes" in the histogram, shown in Figure 122. As the multiplication takes place on the digitized image with the same bit depth as the output image, some luminance levels cannot be reached anymore.

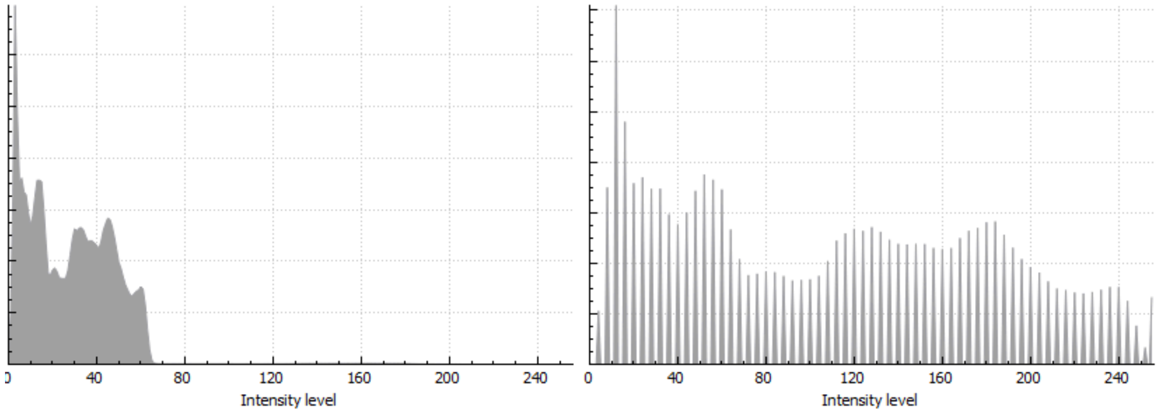


Figure 122: Digital Gain - Histogram original image (left) and after applying digital gain of 4.0 (right)

With a digital gain of 2.0 it is for example not possible to receive any uneven values (1; 3; 5...), like sketched in Table 75. The analog gain is therefore always to be preferred where possible.

Pixel_{In}	$\text{Pixel}_{\text{Out}} = \text{Pixel}_{\text{In}} \times 2.0$
0	0
1	2
2	2
3	6

Table 75: Digital Gain - Output values

Digital Gain in GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface to apply digital gain to images. The bit depths and image types supported are shown in Table 76. For a detailed description on how to use the digital gain feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 76: Digital Gain - supported bit depth and image type

Digital Gain in the GigEVisionClient

In the *GigEVisionClient* the *Digital Gain* can be accessed in the *Image Processing Properties* panel under *Color / Mono*, shown in Figure 123. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

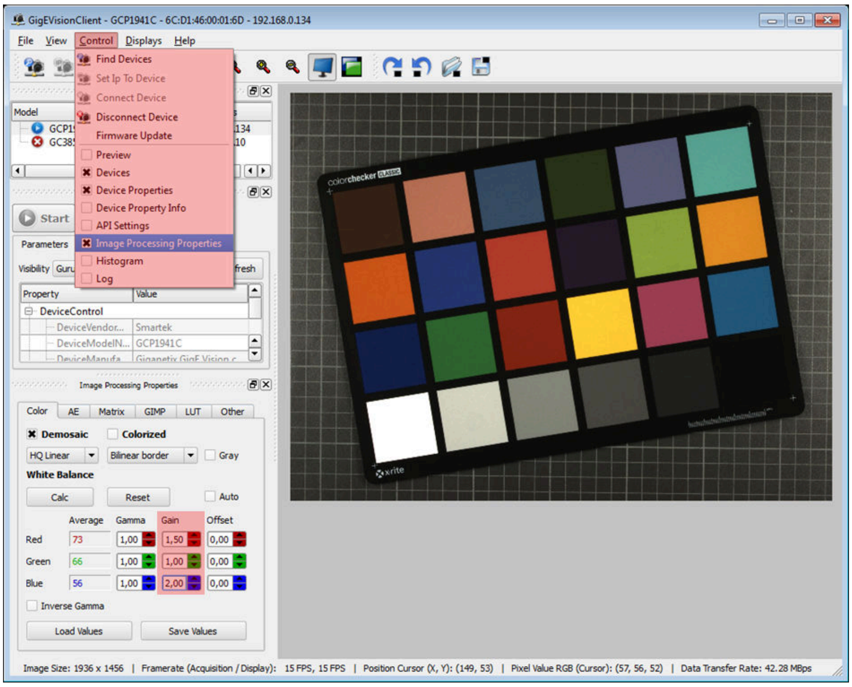


Figure 123: Digital Gain in GigEVisionClient

Note

The Digital Gain is used to apply the White Balancing values to the image. While the "Auto White Balance" option is enabled, a manual configuration of digital gain is not possible.

6.2.3 Auto Exposure and Auto Gain

Cameras are often used in different environments and applications with changing conditions, what also includes the illumination situation which may vary and change constantly. The exposure time determines how bright or dark an image will appear; the longer the exposure, the brighter the image and vice versa. The automatic exposure feature of the *ImageProcAPI* will automatically adjust the exposure time of SMARTEK Vision cameras within defined limits, until the specified target brightness is reached.

Increasing the exposure time means decreasing the maximum possible frame rate, therefore in various applications, where a specific minimum frame rate is required, the exposure time may not be arbitrarily high. In this situation the brightness can be further increased applying a digital gain. The Auto Exposure feature in the *ImageProcAPI* provides therefore a property to limit the maximum allowed exposure time, from which the gain will be increased instead.

Auto Exposure in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface to set parameters and execute the auto exposure algorithm to determine the new exposure time and gain adjustment values. The bit depth and image type supported are shown in Table 77. For a detailed description on how to use the auto exposure feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 77: Auto exposure - supported bit depth and image type

Auto Exposure in the GigEVisionClient

In the *GigEVisionClient* the *Auto Exposure* (AE) can be enabled / disabled in the *Image Processing Properties* panel under *AE* (see Figure 124). If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

Four parameters can be adjusted:

1. **Target Brightness [%] (default 50):** This parameter determines the average brightness of the image which should be reached. For an 8-bit image this value is 127.5, for a 16-bit image 32767.5.
2. **Min Exposure Time [µs] (default 100):** minimum exposure time to be calculated. This value must not match the minimum exposure time of the image sensor, but should not undercut.
3. **Max Exposure Time [µs] (default 300000):** maximum exposure time to be calculated. This value must not match the maximum exposure time of the camera, but should not exceed.
4. **Exposure Time Threshold [%] (default 10):** absolute difference between new exposure and old exposure value. The new calculated exposure value needs to be higher than this threshold value to be considered as the new exposure to be adjusted.

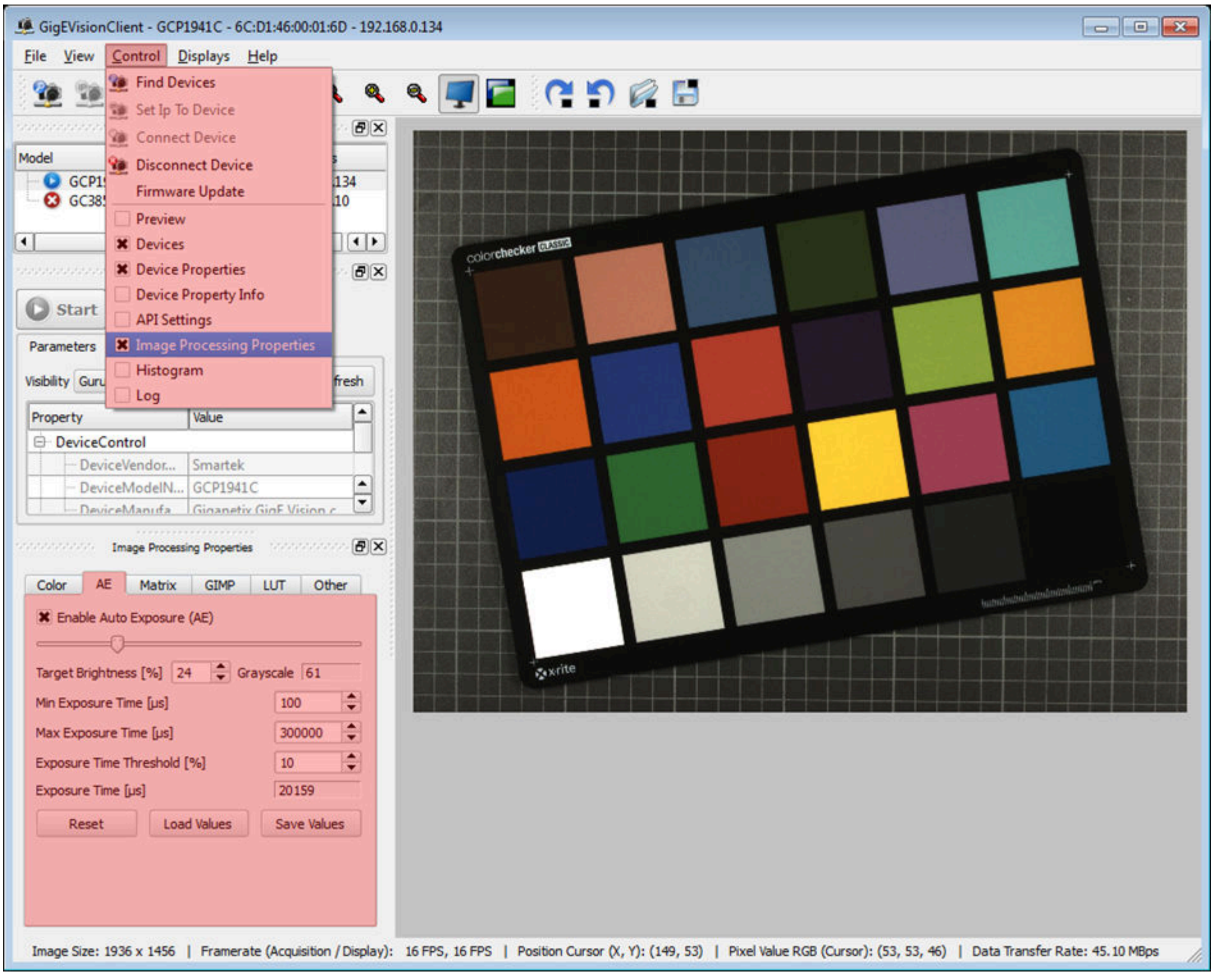


Figure 124: Auto Exposure in GigEVisionClient.

6.2.4 White Balance

White Balancing is the process of removing unwanted color casts in digital images, which derived from one important characteristic of visible light - the color temperature. The color temperature is defined by the radiation emitted by a glowing "black body" and is measured in Kelvin (K). Since an image sensor converts light to electrical voltage which then underruns multiple processing steps until a digital image is saved or displayed on the screen, the color temperature of the light is visible on the digital image in form of color casts appearing to the human eye.

Figure 125 illustrates the color temperature spectrum of visible light in the range from 1000K to 15000K.

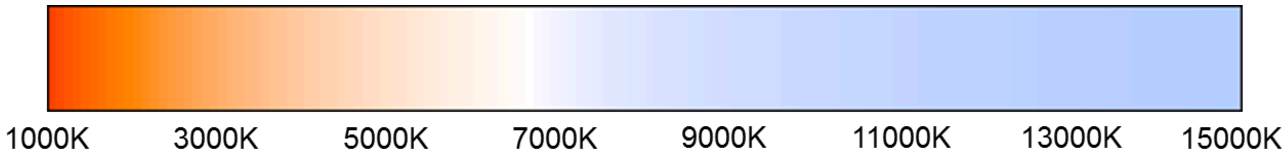


Figure 125: Color temperature spectrum in range 1000K to 15000K

Digital images which are captured in lower color temperature conditions (candle light, tungsten light) tends to be reddish or reddish orange. The higher the color temperature (overcast sky) the more blue light will outweigh, the digital image appears more bluish.

To fully describe color casts in digital images a tint adjustment is also required. While the color temperature determines the warmth or coolness of an image, the tint defines the balance between magenta and green color casts.

Figure 126 shows two images of a color checker chart. The image in the left shows the original values of the patches while the color checker on the right is captured by a camera at day light condition. If we look at the last row of the color chart on the left image, the Gray color fields tend to be green.

Figure 126: Comparison original color (left) and camera image (right) of a ColorChecker chart

Human eyes can automatically correct this effect, for a camera to compensate this effect automatic white balancing is needed to accurately balance color. The white balancing feature implemented in the *ImageProcAPI* adjusts the weighting for each color channel using digital gains in order to remove the unwanted color casts.

Figure 127 demonstrates the White Balancing feature implemented in the *GigEVisionSDK*. The green color cast is corrected, the output image appears as it should.

Figure 127: ColorChecker chart without (left) and with White Balancing (right)

White Balance in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for executing the White Balance algorithm. The bit depth and image types supported are shown in Table 78

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 78: White Balance - supported bit depth and supported image type

For a detailed description on how to use the auto white balance feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

White Balance in the GigEVisionClient

In *GigEVisionClient* the user can apply the *White Balance* algorithm once or repeatedly for every incoming frame. All options can be can be accessed in the *Image Processing Properties* panel under Color shown in Figure 128. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

The single white balance mode is recommended in scenes where the lighting condition is constant, so there will be no computation overhead. The correction values are calculated once when the Calc button is pressed.

The Auto White Balance mode is disabled by default, as soon as enabled by the *Auto White Balance* (AWB) check box it calculates an applies correction gains for every frame. This mode is recommended when the lighting condition may permanently change.

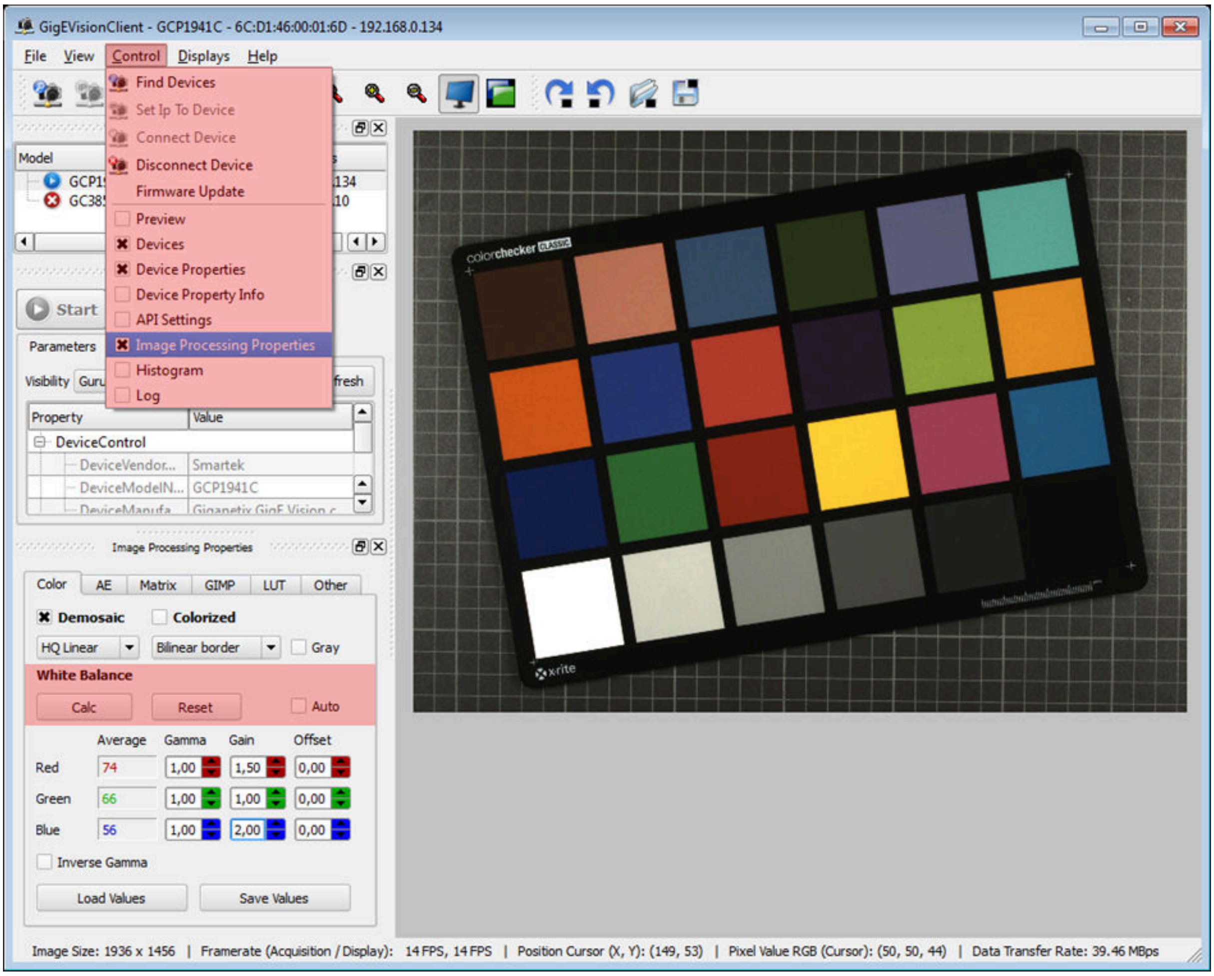


Figure 128: White Balance feature in the GigEVisionClient

- **Calc:** Start white balancing calculation once.
- **Auto:** Repeatedly apply white balancing to the images.
- **Reset:** Reset every results calculated by the white balancing process to default. If auto white balance is enabled before, it will be disabled.

6.2.5 Gamma Correction

Gamma is an important characteristic of digital imaging systems, as it translates between the light sensitivity of the human eye and thus of the image sensor. Generally it has to be distinguished that there are basically two definitions of gamma. The first one is called *Gamma Correction*, the second one *Gamma Adjustment*. The *Gamma Adjustment* assumes that the sensor's gamma is 1.0 and comes into consideration when displaying an image on a display device. It is used to encode linear luminance or RGB values to match the non-linear characteristics of display devices.

Depending on the characteristics of the sensor and also influenced by gain or black level, the gamma output of the camera is not ideally 1.0. If only the Gamma Adjustment is applied to the image, the real gamma may represent a combination of the encoding gamma and the sensor's gamma. The consequence of this effect is that the brightness levels of the image outputted on the display are distorted.

In situations where the gamma of the sensor is not 1.0, the *Gamma Correction* can be used to linearize the non-linear sensor's characteristics to match a linear gamma of 1.0. For this purpose a well calibrated gray scale is usually used to determine the *Gamma Correction* values. The gamma value can be applied using the *ImageProcAPI*.

The term *Gamma Correction* will be used throughout this document and depends on the context, it can be understood as either *Gamma Correction* or *Gamma Adjustment*.

Gamma Correction Workflow

The workflow of correcting gamma is illustrated in Figure 129. First an image of a known and calibrated object like a Color Checker chart will be captured. Based on this the gamma of the sensor can be determined, a sample of a sensor gamma curve is shown in the first block of Figure 129 (from left to right). After applying the *Gamma Correction* value the brightness levels should match the values known from the calibration chart and represent a Gamma of 1.0.

If it is intended to display the image to the human eye the gamma of the display device should be known. Based on the device's gamma the *Gamma Adjustment* process could be started, encoding linear luminance to match the non-linear characteristics of the display device; a common display gamma value is 2.2. After gamma adjustment the displayed image appears luminance correct on the display device.

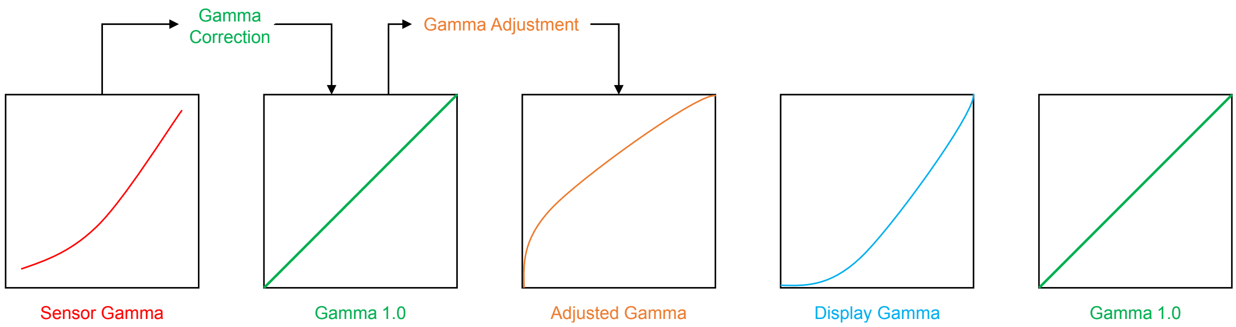


Figure 129: Gamma correction workflow

Gamma curves are defined by the following formula, where x is the percentage input luminance, y the percentage output luminance, a the darkest percentage brightness value (ideally 0), b the digital gain and c the gamma.

$$y = a + bx^c$$

Further x can be determined based on the bit depth n by the following formula:

$$x = \frac{\text{pixelvalue}}{2^n - 1}$$

The appropriate gamma curve can be determined by capturing an image of a calibrated gray scale showing a linear progression over a brightness of 0% to 100%.

Gamma Correction in GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for setting and executing the gamma correction algorithm. The bit depth and image types supported are shown in Table 79. For a detailed description on how to use the digital offset, gain and gamma correction feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 79: Gamma Correction - supported bit depth and image type

Gamma Correction in GigEVisionClient

In the *GigEVisionClient* Gamma, Gain and Offset can be accessed in the *Image Processing Properties* panel under *Color / Mono*, shown in Figure 130. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

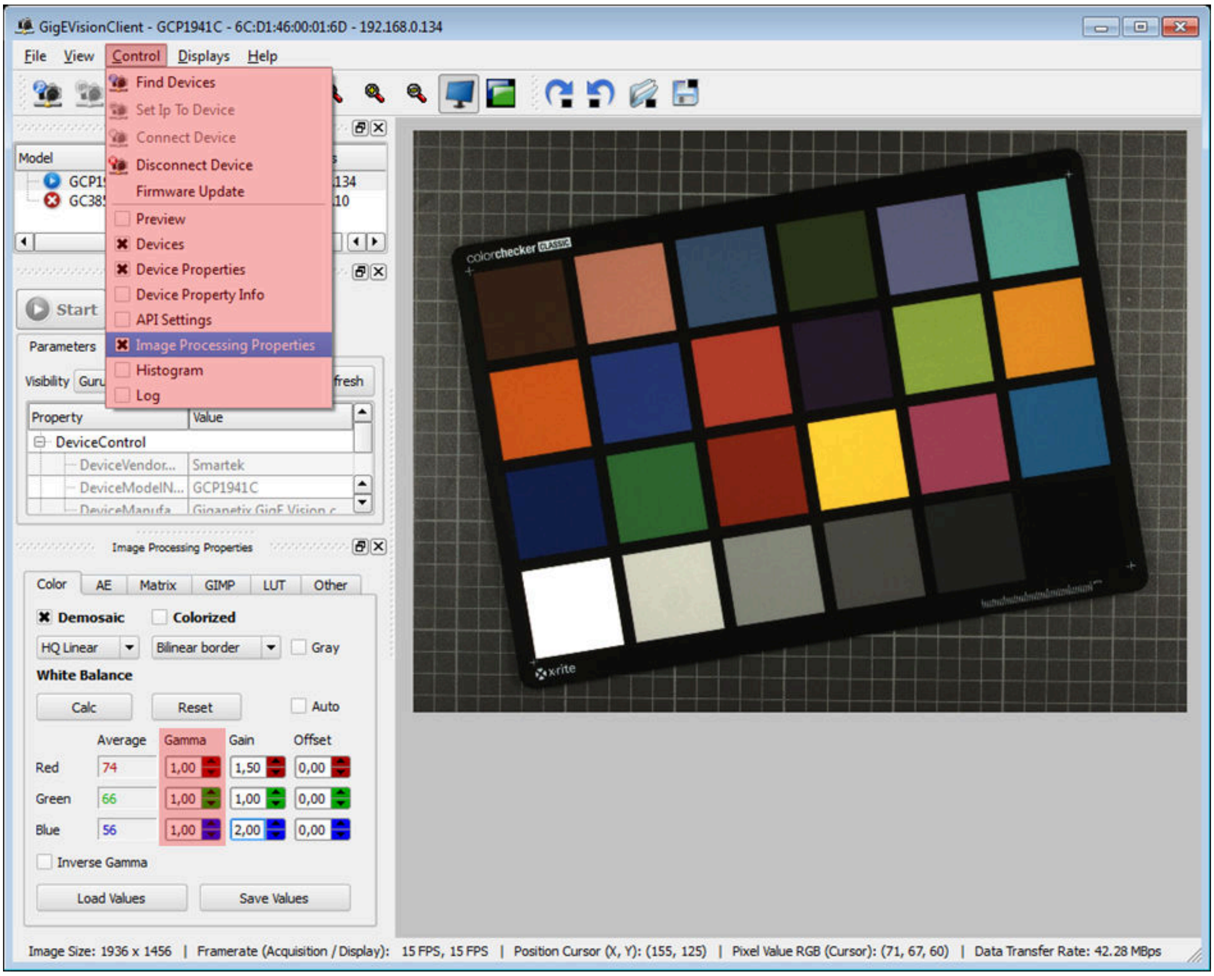


Figure 130: Gamma Correction dialog

6.2.6 Color Filter Array Interpolation (Demosaicing / Debayering)

Each pixel on a digital camera sensor contains a light sensitive photo diode which measures the amount of incoming light. As photodiodes are monochromatic devices, they are unable to determine the distribution of the incoming light to different wavelengths. A common way to distinguish between different light wavelengths or colors is to place an array of color filters (*Color Filter Array*; CFA) on top of the sensor to filter out for example the red, green, and blue components of light falling onto it. Among many CFA patterns, the most commonly used is the Bayer pattern. For each 2×2 set of pixels, two diagonally opposed pixels are equipped with filters which are only transmissive for green, the other two only for red and blue. Since green carries most of the luminance information for the human eye, its sampling rate is twice as that of R and B. Figure 131 shows the "GR" filter alignment, which means that the pattern starts with green (G) followed by red (R).

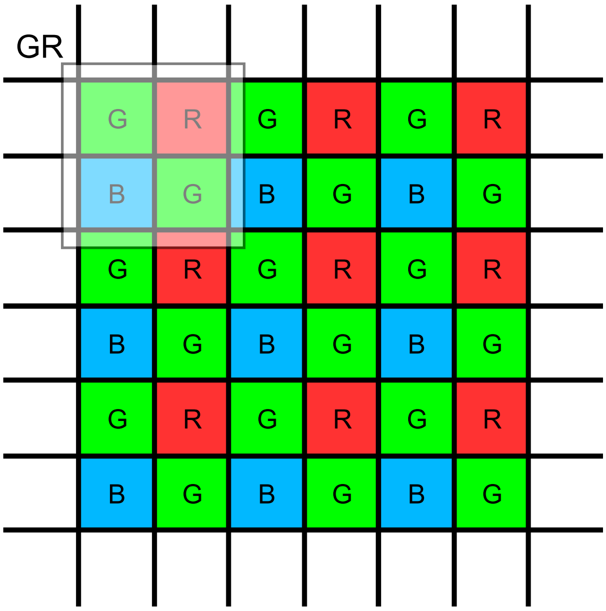


Figure 131: Bayer Filter Pattern GR

The illustration in Figure 131 is for demonstration purposes only. In effect, each pixel is described by an intensity value, which appears gray to the human eye, shown in Figure 132.

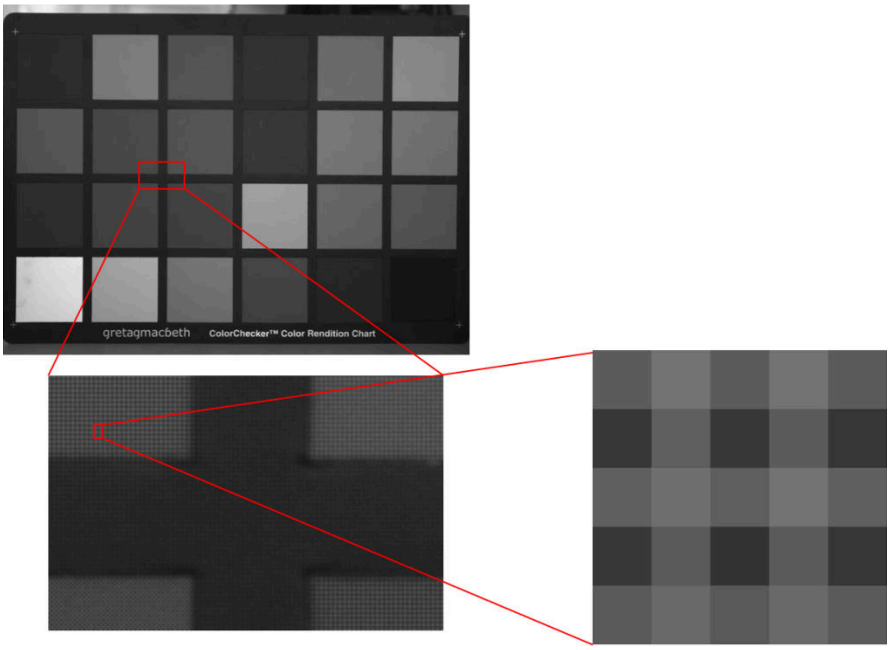


Figure 132: Raw image overlaid with a Bayer pattern

Figure 132 shows a raw image from a color camera. If it is zoomed into the image, the Bayer pattern gets more and more visible. Each pixel represents an intensity value, to reconstruct a full color image from the incomplete color samples, the missing color information at each pixel has to be interpolated. The interpolation process has several different names like *Color Filter Array Interpolation, Demosaicing or Debayering*. The reconstructed image is typically accurate in uniform-colored areas, but has a loss of resolution especially at structures and edges.

There are different interpolation methods where each of them has its own strengths and weaknesses. In the *ImageProcAPI* three algorithms are implemented, namely *Bilinear Interpolation*, *High Quality Linear Interpolation* and *Pixel Group Interpolation*.

Bilinear Interpolation

The *Bilinear Interpolation* is a linear demosaicing method using a 3-by-3 filter for color interpolation. For each pixel its 8 direct neighbors are considered to determine the 2 missing colors of this pixel by simple averaging. The red value of a non-red pixel is computed as the average of the two or four adjacent red pixels, and similarly for blue and green.

The bilinear method has the lowest complexity as there are only a few calculations per pixel, compared to the other algorithms. It thus shows the lowest workload, but is much more imprecise at e.g. structures and edges in the image. Because of the small amount of calculations, also the memory usage is negligible compared to HQ Linear Interpolation.

HQ Linear Interpolation

The *HQ Linear interpolation* is a gradient-corrected bilinear interpolated method using a 5x5 linear filter. In contrast to the bilinear method, the HQ Linear interpolation correlates different color channels to calculate the missing color value. For example, the red value of a non-red pixel is computed as the average of the two or four adjacent red pixels (depending on the amount of red pixels in the 5x5 neighborhood) plus a correction value calculated from pixels of a different color channel.

In comparison with the bilinear interpolation, the *HQ Linear interpolation* method has the modest increase in computational complexity. However, the main advantage of this method is that it generates significant higher quality color images with greatly reduced edge artifacts. Therefore *HQ Linear interpolation* is in the *GigEVisionSDK* used as the standard demosaicing algorithm.

Pixel Group Interpolation

Pixel Grouping is another interpolation method considering pixel values in a 5x5 neighborhood to calculate missing color values. It basically works in two phases; first it computes all the unknown green values, and then it uses the input data along with the green values computed in the first phase, to compute all the missing red and blue values. The main principle is to determine the gradients in the four directions from the current processed pixel and select the value with the smallest one for final calculation. The smallest gradient value is chosen to reduce edge artifacts due to the fact that a higher gradient value is an indication for edge transition.

In comparison with the *bilinear* and *HQ Linear interpolation* methods, *Pixel Grouping* is the most memory and computational intensive algorithm. However, the result color image is at very high quality with very little edge artifacts, especially for scenes with large areas of uniform colors that are separated by clear boundaries.

Colorized Output

The Colorized algorithm is not doing any interpolation. It simply creates an intensity Bayer RGB color image by setting the missing color values to zero. The intensity value of the current pixel remains unchanged.

Restrictions at the Image Borders

Nearly all interpolation methods have problems at the borders of the image. Depending on the size of the filter used (3x3, 5x5, ...), one or more neighbors in each direction are needed for interpolation; at the borders at least one direction is not available, like illustrated in Figure 133 and Figure 134 for *Bilinear* and *HQ Linear*.

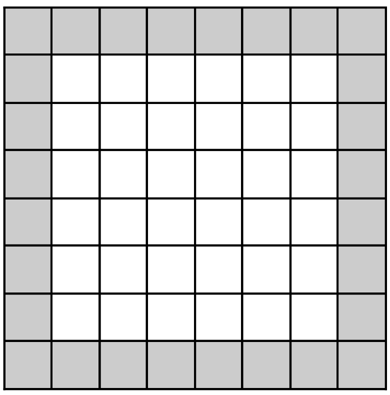


Figure 133: Bilinear algorithm border

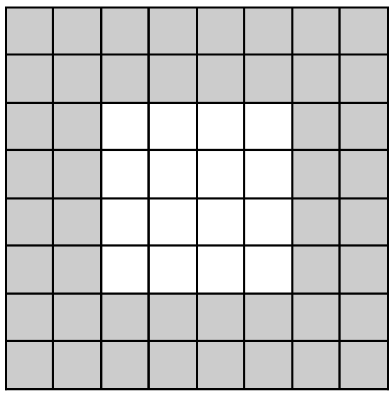


Figure 134: HQ Linear algorithm border

The ImageProcAPI therefore provides four approaches:

- leave border pixels as original (RAW)
- cut off border pixels
- fill border pixels with a solid color
- interpolate border pixels with a specific demosaicing algorithm

Demosaicing in GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for configuring and executing the demosaicing operations within user applications. The bit depths and image types supported are shown in Table 80. For a detailed description on how to use the demosaicing feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome		
Raw Bayer	✓	✓
Color RGB		

Table 80: Demosaicing - supported bit depth and image type

Demosaicing in GigEVisionClient

In the *GigEVisionClient* the demosaicing options can be accessed in the *Image Processing Properties panel* under *Color*, shown in Figure 135. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

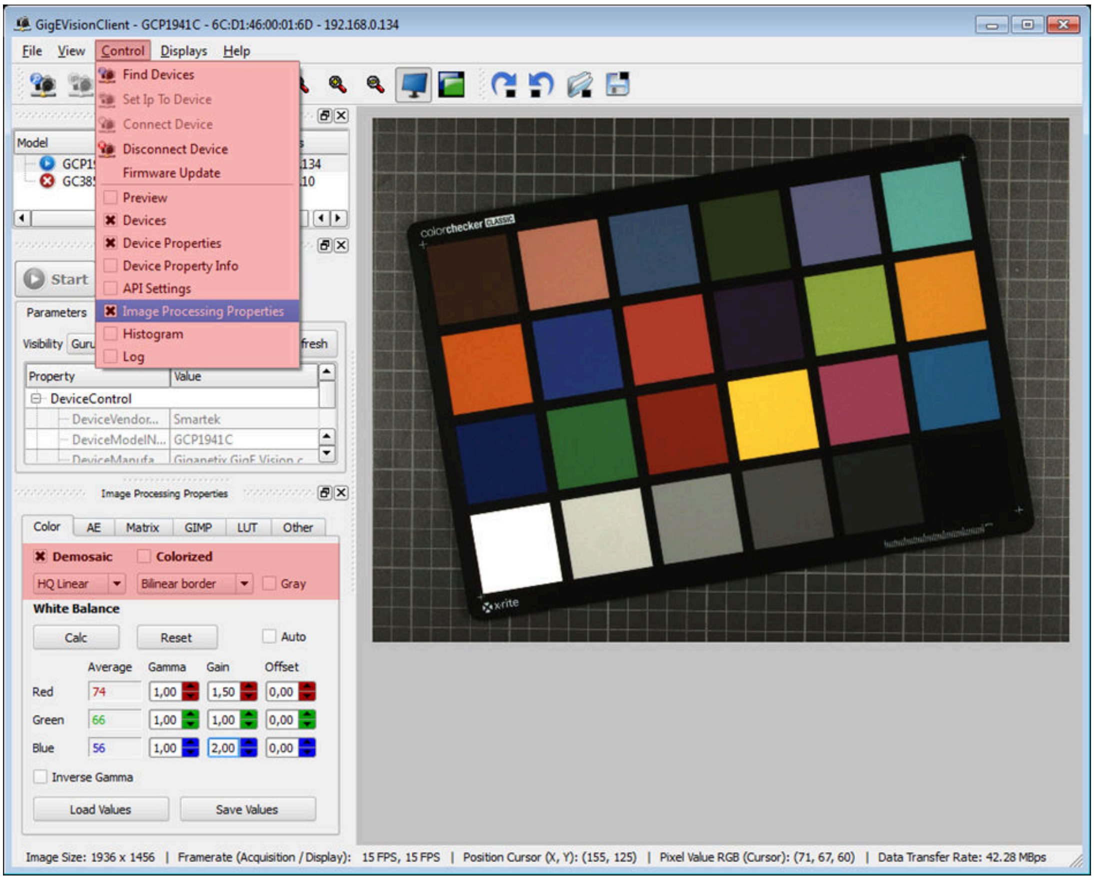


Figure 135: Demosaicing algorithms with border type selection

6.2.7 Matrix Multiplication 3x3

N-by-N matrices are commonly used to transform RGB colors, scale them and control hue, saturation and contrast. The *GigEVisionSDK* provides a configurable 3-by-3 matrix for various applications, modifying color images using matrix multiplication operations.

Note: For these operations to be correct, they must be operated on linear brightness values. If the input image is in a non-linear brightness space, RGB colors must be transformed into a linear space before these matrix operations are used.

Figure 136 shows how the matrix multiplication is done, where m_{xx} are the matrix elements, R_i / G_i / B_i are the input original values for the red, green and blue channel and R_o / G_o / B_o are the output color values for the red, green and blue channel.

$$\begin{bmatrix} m_{00} & m_{01} & m_{02} \\ m_{10} & m_{11} & m_{12} \\ m_{20} & m_{21} & m_{22} \end{bmatrix} \times \begin{bmatrix} R_i \\ G_i \\ B_i \end{bmatrix} = \begin{bmatrix} R_o \\ G_o \\ B_o \end{bmatrix}$$

Figure 136: Matrix Multi RGB parameters and results

In effect, this calculates:

$$\begin{aligned} R_o &= m_{00} \cdot R_i + m_{01} \cdot G_i + m_{02} \cdot B_i \\ G_o &= m_{10} \cdot R_i + m_{11} \cdot G_i + m_{12} \cdot B_i \\ B_o &= m_{20} \cdot R_i + m_{21} \cdot G_i + m_{22} \cdot B_i \end{aligned}$$

Common applications for the 3x3 matrix operation are for example color correction, color balancing and the conversion from color to luminance.

Matrix Multiplication 3x3 in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface to configure and execute the 3x3 matrix multiplication algorithm. The bit depths and image types supported are shown in Table 81.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 81: Matrix Multiplication - supported bit depth and image type

Matrix Multiplication 3x3 in the GigEVisionClient

In the *GigEVisionClient* the demosaicing options can be accessed in the *Image Processing Properties* panel under Matrix, shown in Figure 137. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

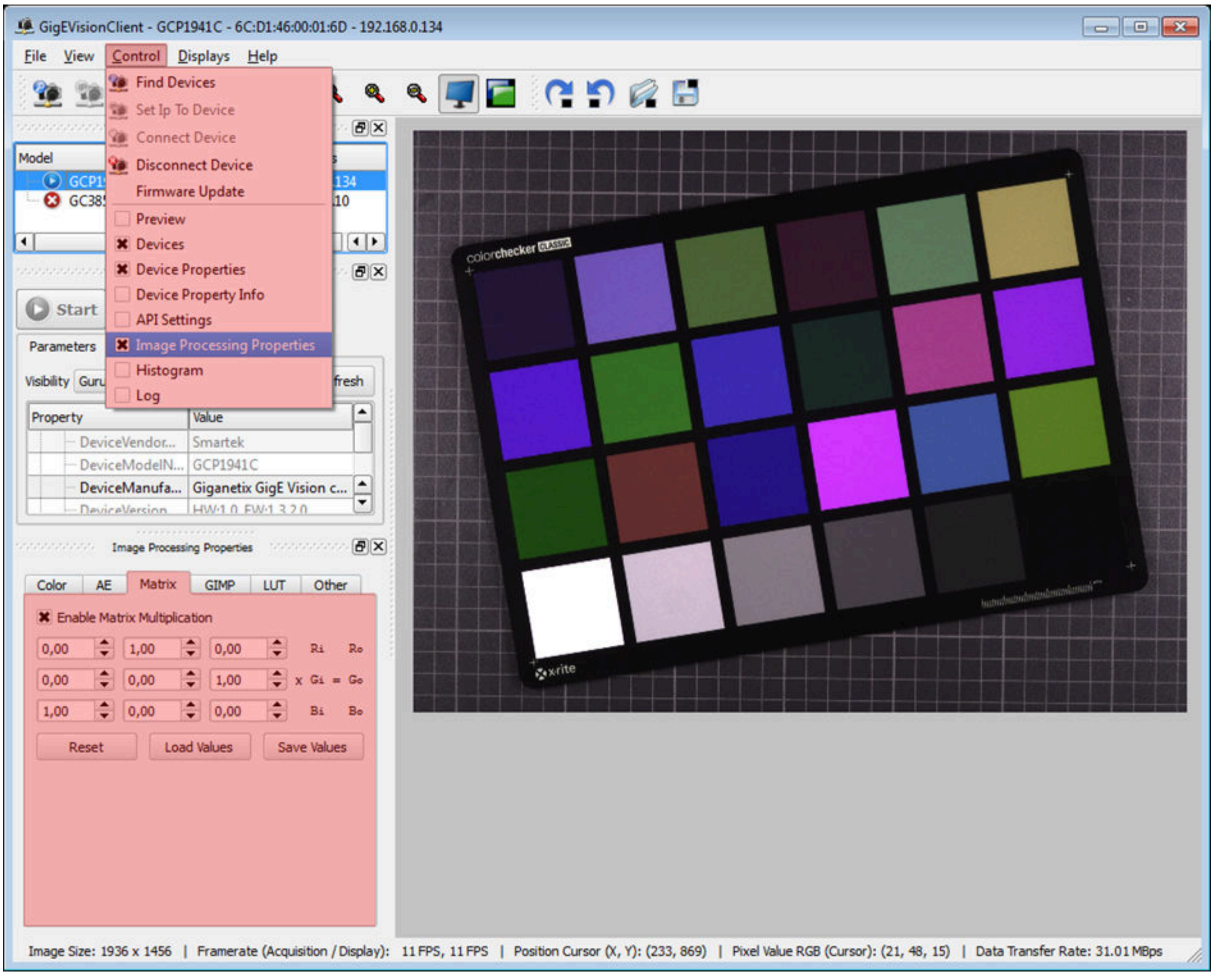


Figure 137: Matrix Multiplication RGB in the GigEVisionClient

- **Enable:** Activate / deactivate the matrix multiplication feature
- **Reset:** Sets matrix coefficients to default values
- **Load Values:** Load a file with user-defined matrix coefficients
- **Save Values:** Save the current matrix coefficients to a file

6.2.8 GIMP HSL

The *GIMP HSL* algorithm allows the color manipulation of images based on the HSL color space. The used algorithm is provided by the open source project GIMP and allows the manipulation by the attributes *Hue, Saturation and Lightness*.

When it comes to manipulating color in images it is often referred to color models or color spaces. Basically a color model describes the way colors can be represented. With understanding of how different color models work, the appropriate color model for specific image processing algorithms can be chosen. The most widely used and best known one is the RGB color model. However, RGB is not always efficient and intuitive in manipulating color.

A more suited color space for manipulating colors is the HSL color space. It was developed to interpret colors in a very similar way as humans do, wherefore color and brightness information are handled separately. The color information is defined by *Hue* and *Saturation*, the brightness information is defined by a *Lightness* value. The HSL color model can be represented by a circle called a color wheel like shown in Figure 138.

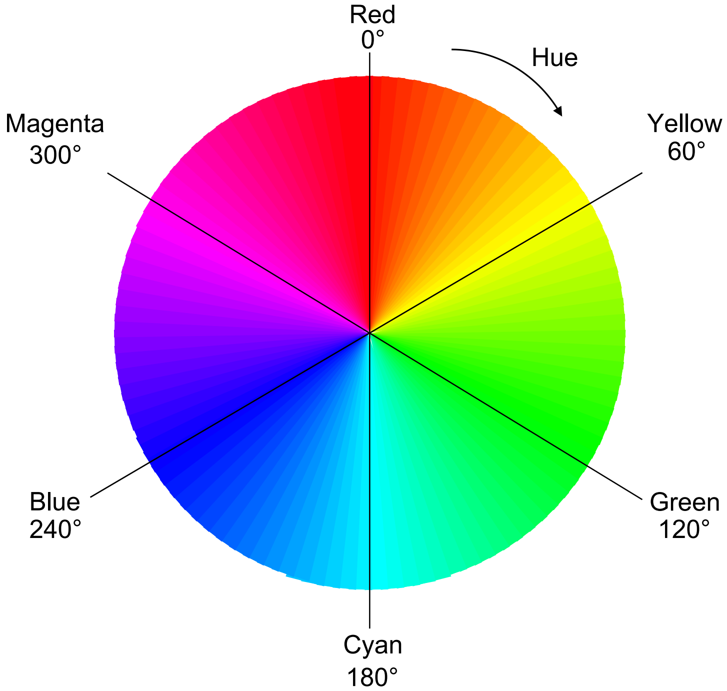


Figure 138: HSL color wheel

Hue refers to a specific tone of color: Red, Yellow, Green, Cyan, Blue, Magenta and their blends, the individual colors are arranged in a circle. Their individual position is determined by an angle, ranging from 0° to 360°. Pure red is usually placed at 0°, pure green and pure blue at 120° respectively 240°. Table 82 shows the six base colors.

Hue (angle)	Color
0°	red
60°	yellow
120°	green
180°	cyan
240°	blue
300°	magenta

Table 82: HSL color space

As shown in Figure 138 as well, *Saturation* describes the intensity of a color. It defines how pale or strong a color appears and is the intensity of a Hue from gray. At maximum saturation a color would contain no gray at all, at minimum saturation a color would contain mostly gray. In the HSL color wheel the saturation specifies the distance from the middle of the wheel in percent.

Lightness describes how bright or how dark a color appears. It defines how much white or black is contained within a color.

Because of its characteristics of separating color and brightness information, the HSL color space fits for various image processing functions such as convolution, equalization, histograms, which mainly use the brightness information for calculation. As a result, computation performance may also increase due to performing calculation only on one channel.

Gimp HSL in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for configuring and executing *Gimp HSL* algorithm. The bit depth and image type supported are shown in Table 83. For a detailed description on how to use this feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome		
Raw Bayer		
Color RGB	✓	

Table 83: Gimp HSL - supported bit depth and image type

Gimp HSL in the GigEVisionClient

In the *GigEVisionClient* the *GIMP HSL* manipulation options can be accessed in the *Image Processing Properties* panel under GIMP, shown in Figure 139. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*. If Master is selected, then values are changed for every channel at once.

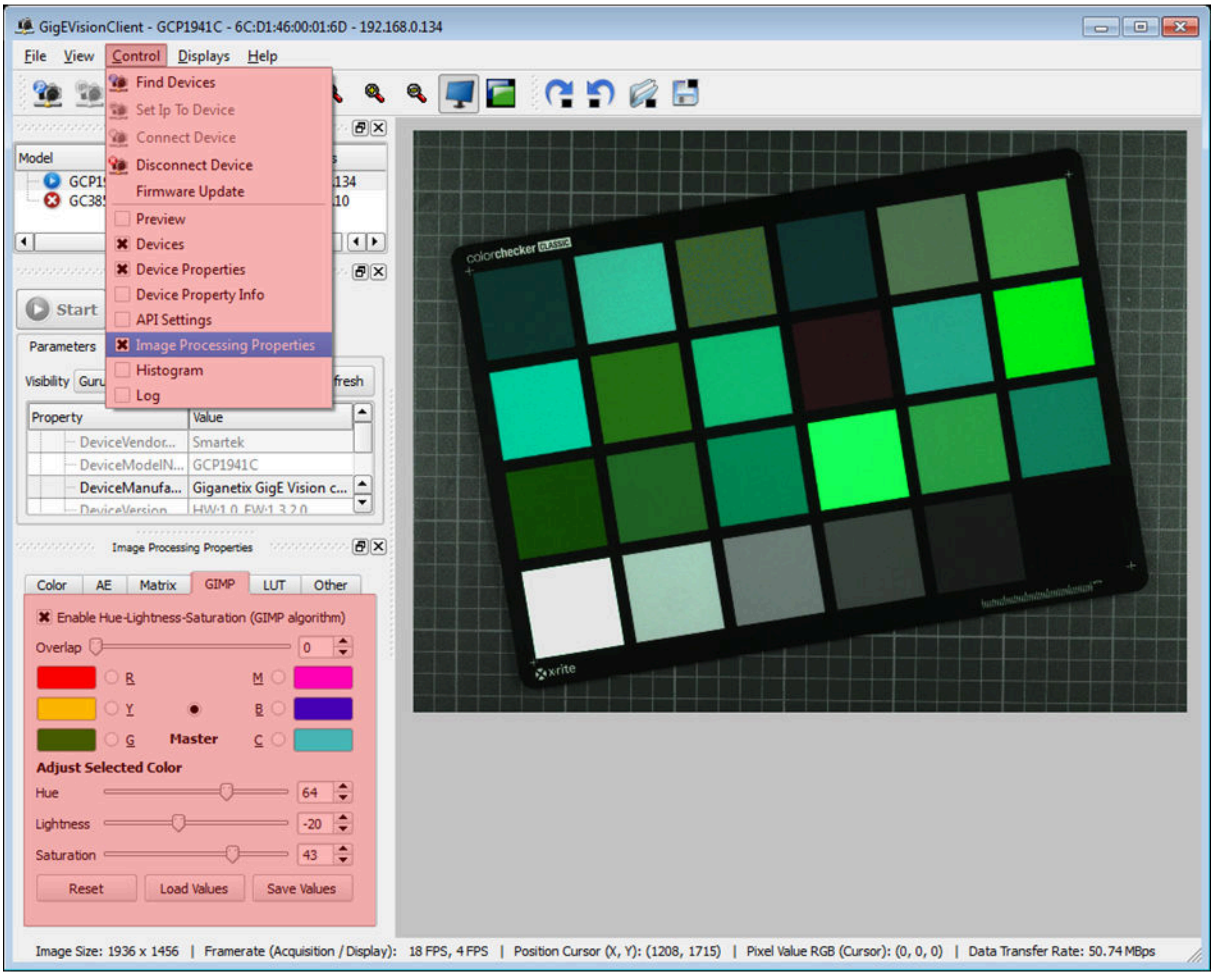


Figure 139: Color GIMP dialog

- **Enable:** activate / deactivate the GIMP Hue / Saturation / Lightness processing
- **Reset:** Sets all settings to default values
- **Load Values:** Load an file with user-defined Hue, Saturation and Lightness values
- **Save Values:** Save the current Hue, Saturation and Lightness values to a file

6.2.9 Sharpening

In some situations captured images are blurred, where the reasons may vary; imperfect produced lenses or digital image sensors themselves can blur an image to some degree as well as motion in the scene and image operations which may reduce the sharpness. Especially on Bayer color image sensors, where the missing color information is interpolated, a loss of sharpness is unavoidable.

Sharpening emphasizes edges and fine details in the image, enhancing its visual quality. The image seems sharper, but no new details are actually created.

Figure 140 demonstrates the sharpening algorithm of the *ImageProcAPI*. On the left the original image is displayed, on the right the sharpened image with an applied sharpen factor of 1.0. As result the output image appears sharper in comparison to the original one.

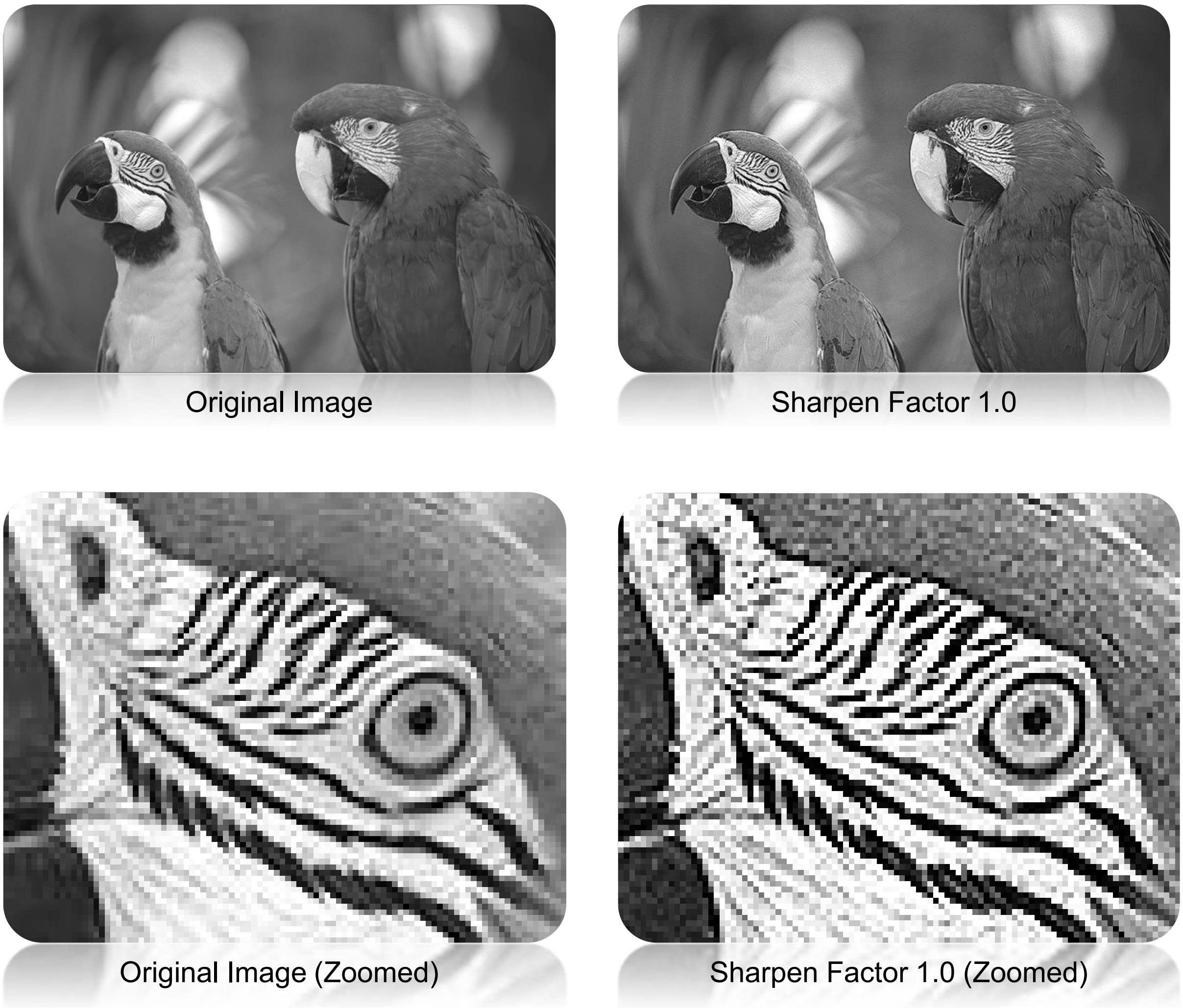


Figure 140: Example of sharpening algorithm (factor 1.0)

Sharpening in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for configuring and executing the sharpening algorithm. The bit depths and image types supported are shown in Table 84. For a detailed description on how to use this feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer		
Color RGB	✓	✓

Table 84: Sharpening - supported bit depth and image type

Sharpening in the GigEVisionClient

In the *GigEVisionClient* the *Image Sharpen* options can be accessed in the *Image Processing Properties* panel under *Other*, shown in Figure 141. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

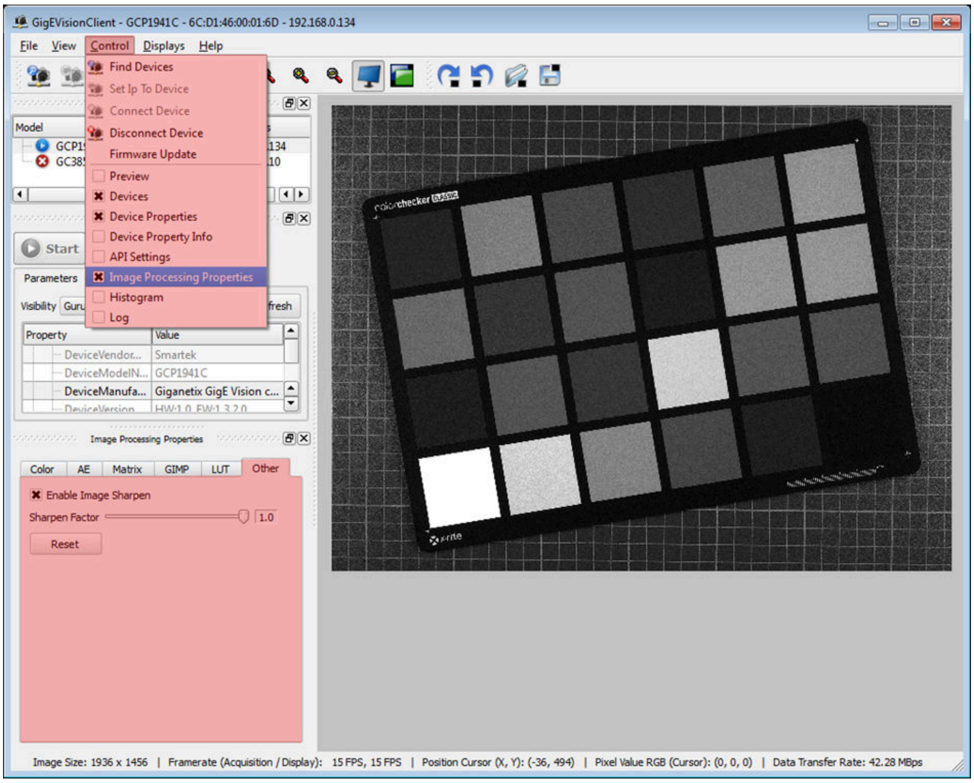


Figure 141: Sharpening in the GigEVisionClient

- **Enable:** Activate / deactivate the image sharpening feature
- **Reset:** Sets the sharpen factor to the default value

6.2.10 RGB to Grayscale Conversion

Color images often have to be converted to grayscale, providing input data for subsequent digital image processing like edge detection filers, OCR etc. The RGB-to-grayscale conversion performs a reduction of the RGB color data into a single channel luminance image.

Figure 142 shows an example of RGB-to-gray conversion. The image on the left represents the original RGB color image. The output grayscale image on the right is the result of the conversion process.

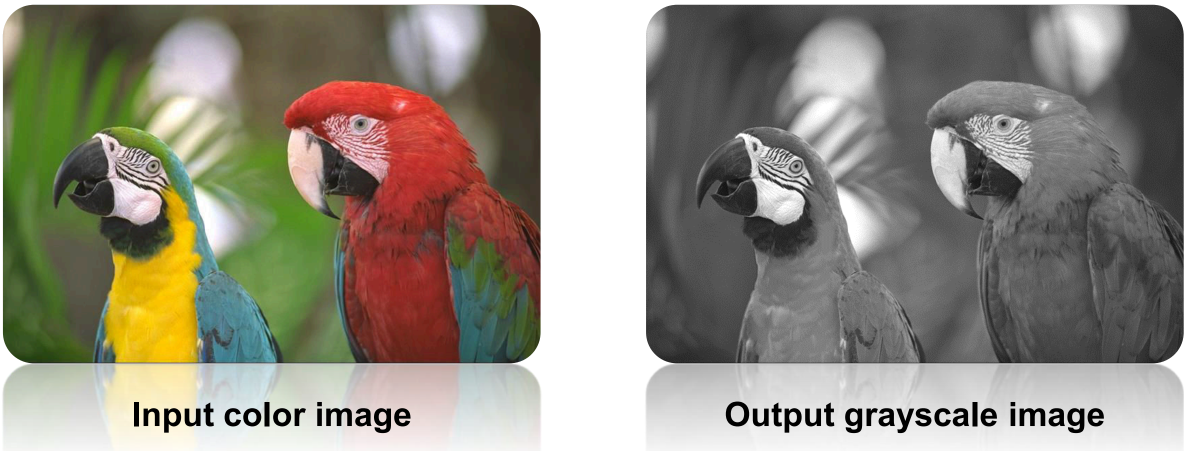


Figure 142: Example of RGB-to-gray conversion

RGB-to-Gray Conversion in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for executing the RGB-to-gray conversion. The bit depths and image types supported are shown in Table 85. For a detailed description on how to use this feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome		
Raw Bayer		
Color RGB	✓	✓

Table 85: RGB to Gray conversion - supported bit depths and image types

RGB-to-Gray Conversion in the GigEVisionClient

In the *GigEVisionClient* the RGB-to-Gray options can be activated in the *Image Processing Properties* panel under *Color*, shown in Figure 143. If not visible, the panel can be enabled by the menu bar entry *Control* ⇒ *Image Processing Properties*.

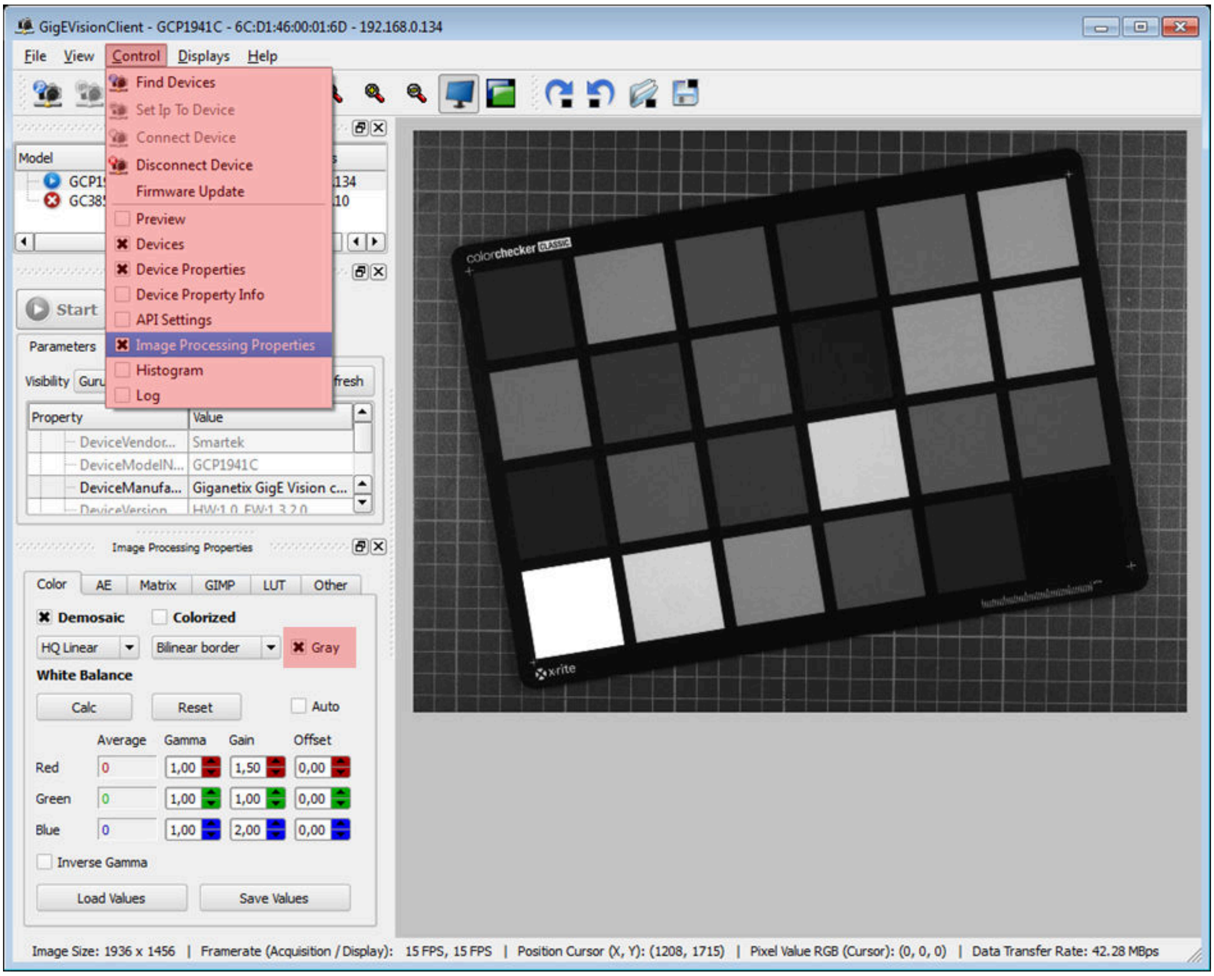


Figure 143: RGB to Gray conversion in GigEVisionClient

6.2.11 Bit Depth Conversion

The bit depth of a pixel describes the resolution with which the luminance information is handled. As usual display devices only support 8 bit per channel, the Bit Depth Conversion algorithm there allows the conversion from 16 bit down to 8 bit and vice versa.

Converting images from a higher bit depth to a lower one will lead to reduction of the image size. Please keep in mind that this conversion causes information loss which cannot be recovered by the back conversion to a higher bit depth.

Bit Depth Conversion in the GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for converting the bit depth of an image. The bit depths and image types supported are shown in Table 86.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB	✓	✓

Table 86: Bit depth conversion - supported bit depth and image type

For a detailed description on how to use this feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

Bit Depth Conversion in the GigEVisionClient

The Bit Depth Conversion function is automatically applied to 16 bit per channel images to display them on the screen. The inverse conversion from 8 bit to 16 bit is therefore not relevant in the *GigEVisionClient*.

6.3 Color Image Processing Pipeline

In the previous chapters the image processing algorithms provided by the *ImageProcAPI* in of the *GigEVisionSDK* have been introduced. Within user applications all image processing algorithms can be combined together in a non-specific order.

The *Image Processing Pipeline* performs the baseline and provides the whole chain in a process optimized way, improving the interaction of all algorithms and thus the overall performance. It takes the raw data produced by a camera sensor and generates the digital image that will then undergo further processing, is viewed by the user and/or stored to a nonvolatile memory.

The preconfigured imaging pipeline supported by the ImageProcAPI is illustrated in Figure 144.

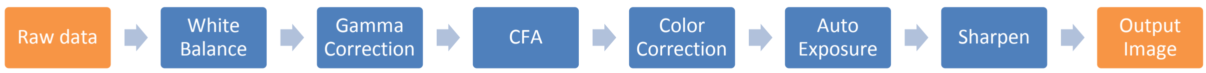


Figure 144: Image Processing Pipeline

The order of the algorithms in the color image pipeline provided by the *GigEVisionSDK* is fixed and cannot be modified, only the parameters and the execution of each algorithm can be configured. For other cases a custom image processing pipeline can by combined by the available algorithms in a preferred order.

Color Image Processing Pipeline in GigEVisionSDK

In the *GigEVisionSDK* the *ImageProcAPI* provides the programming interface for executing the predefined color image processing pipeline within user applications. The bit depths and image types supported are shown in Table 87. For a detailed description on how to use this feature please refer to the *GigEVisionSDK API Help* located in the doc folder of the *GigEVisionSDK* installation directory.

	Supported bit depth	
Supported image input	**8 bit per channel**	**16 bit per channel**
Monochrome	✓	✓
Raw Bayer	✓	✓
Color RGB		

Table 87: Color pipeline - supported bit depth and supported image type

Color Image Processing Pipeline in GigEVisionClient

The color image processing pipeline is enabled by default for color cameras. The user only can activate or deactivate a specific algorithm or configure the parameters for each algorithm; the order of the pipeline cannot be changed.

7 Contact Information

Published by:

Smartek d.o.o.
Bana Josipa Jelacica 22c
HR-40000 Cakovec
Croatia

www.SMARTEKvision.com

Email: info@SMARTEKvision.com
Tel: +49 (89) 381 53 30 - 57
Fax: +49 (89) 381 53 30 - 58

For further information please contact our sales partners.